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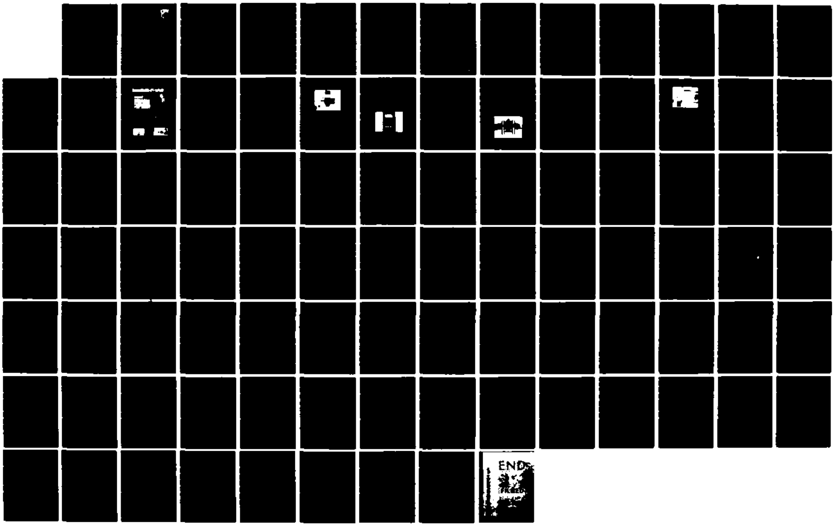

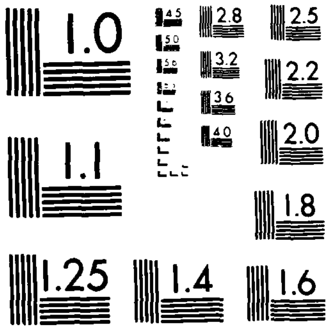

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COMPUTER GENERATED PICTORIAL STORES MANAGEMENT DISPLAYS FOR FIGHTER AIRCRAFT

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May 1983

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This technical report has been reviewed and is approved for publication.

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Four methods for presenting stores information on a cathode ray tube (CRT) were evaluated to determine which is best in terms of pilot performance: 1) alphanumeric format, 2) monochrome pictorial format, 3) color pictorial format, and 4) alphanumeric and color pictorial format. Results indicated that pilots performed equally well with the alphanumeric, color pictorial, and alphanumeric/color pictorial formats but that performance with the black and white pictorial format was significantly worse than all three of these formats. Subjective data indicated significant pilot preference for the alphanumeric/color pictorial

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format. These results indicate one potential advantage of color pictorial formats in the cockpit. Mainly, in addition to the specific information provided by the alphanumeric format, the color pictorial format provides a "situational awareness" where the pilot can obtain important information at a glance. Also supported by this study is the continued exploration of color computer graphics in the cockpit to increase the efficiency of information transfer between the pilot and the aircraft.

FOREWORD

This technical report is the result of a work effort performed by the Display Information Interface Group of the Crew Systems Development Branch (FIGR), Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. Mr. Robert Bondurant III was the group leader and Lt. Anthony Aretz, Capt. Carole Jean Kopala, and Dr. John Reising were responsible for human factors. Mr. Emmett Herron of the Bunker Ramo Corporation provided pilot inputs to the work efforts, and Ms. Gloria Calhoun of the same company provided statistical and experimental design support. Software support was provided by Mr. Tim Berry and Mrs. Debra Park of the Bunker Ramo Corporation; hardware support was provided by Mr. Al Meyer of Technology Incorporated. The objective of this effort was to determine the feasibility of applying pictorial and color coding techniques to a stores status display which presents information to the pilot pertaining to the status of stores that are being carried by the aircraft.

The Bunker Ramo portion of the work effort was performed under USAF Contract Number F33615-78-C-3614. The contract was initiated under Task Number 240304, "Control-Display for Air Force Aircraft and Aerospace Vehicles," which is managed by the Crew Systems Development Branch (AFWAL/FIGR), Flight Control Division, Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories.

The final manuscript was typed by Wanda Kelley, of The BDM Corporation, under Contract F33615-81-C-3620.

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GLOSSARY OF TERMINOLOGY

AAE - Average Absolute Error - A summary statistic descriptive of the error amplitude distribution of a sample of tracking performance. Specifically, it is the mean of the amplitude distribution replotted with all error amplitudes positive. It is an indicator of variability.

AE - Average Error - A summary statistic descriptive of the error amplitude distribution of a sample of tracking performance. Specifically, it is a numerical index of the central tendency of the amplitude distribution.

CCIP AUTO FLIGHT SEGMENT - CCIP - (Continuously Computed Impact Point) AUTO is an A-7 bomb mode used to attack visually acquired targets using dive or low altitude level delivery.

ELECTRO-OPTICAL DISPLAY - A programmable electronic display on which a variety of symbology can be shown.

KOLMOGOROV-SMIRNOV TEST - A one-sample goodness of fit test to determine if the distribution of a set of sample values differs from the normal distribution. Used to analyze questionnaire rating-scale data.

KRISHNAIAH FINITE INTERSECTION TESTS (FITs) - A set of tests conducted after significant MANOVA results are found to determine: 1) which of the dependent variables were most sensitive to changes in independent variables; and 2) which of the experimental groups differed significantly from each other.

MULTIFUNCTION CONTROL (MFC) - Combines several multifunction switches, whose functions change depending upon the task being performed by the operator, on a single panel.

MULTIFUNCTION CONTROL LOGIC - The steps by which pilots execute tasks using the MFC.

MULTIVARIATE ANALYSIS OF VARIANCE (MANOVA) - A statistical procedure which takes into account the fact that several partially correlated dependent variables may be affected by experimental manipulation, and which can determine significant differences in experimental conditions.

ROOT-MEAN-SQUARE ERROR (RMS) - A summary statistic descriptive of the error amplitude distribution of a sample of tracking performance. Specifically, it is an index of performance variability that is relative to the null point.

STANDARD DEVIATION (SD) - A summary statistic descriptive of the error amplitude distribution of a sample of tracking performance. Specifically, it reflects the variability or dispersion of the measures around the central tendency (as indexed by the absolute error or AE).

STORE - A weapon or payload that is carried by an aircraft.

SUMMARY

Four methods for presenting stores information on a cathode ray tube (CRT) were evaluated to determine which is best in terms of pilot performance: 1) alphanumeric format, 2) monochrome pictorial format, 3) color pictorial format, and 4) both alphanumeric and color pictorial formats. The alphanumeric format was chosen for evaluation because the capability to present alphanumeric information is within the state of the art (e.g. F-16 and F-18). The monochrome pictorial format was chosen to investigate the feasibility of pictorially coding information through the use of computer generated imagery (CGI). The color pictorial format was chosen to investigate the additional use of color coding techniques because the beneficial effects of color coding tend to be contextually dependent (Reference 1). And finally, the color pictorial and alphanumeric formats were used together to determine the effectiveness of using both methods concurrently.

Results indicated that pilots performed equally well with the alphanumeric, color pictorial, and alphanumeric/color pictorial formats, but that performance with the black and white pictorial format was significantly worse than the other three formats. Subjective data indicated significant pilot preference for the alphanumeric/color pictorial format. These results indicate one potential advantage of color pictorial formats in the cockpit. Mainly that, in addition to the specific information provided by the alphanumeric format, the color pictorial format provides a "situational awareness" where the pilot can obtain important information at a glance. Also supported by this study (due to strong pilot preference) is the continued exploration of color computer graphics in the cockpit to increase the efficiency of information transfer between the pilot and the aircraft.

SECTION I

INTRODUCTION

Present day fighter aircraft and those currently under development differ substantially from their predecessors not only in their relative flight performance, but more importantly in their sophistication as combat weapon systems. Rapid technological advancements in flight control, aircraft performance, and airborne weapons have increased the potential effectiveness of modern fighters in tactical situations. These same technological advances, however, have also increased the amount of information that can be presented to the pilot and outstripped the ability of crew stations to present this information in an efficient manner. This trend has lead to a situation of information overload which severely increases pilot workload, hindering the pilot's ability to make timely and valid control inputs. The end result is a possible decrease in mission effectiveness.

The solution to this problem is to design crew stations so that the information interface between the pilot and the aircraft is as efficient as possible. One approach to accomplish this task is to replace traditional electro-mechanical devices with computer-driven, electro-optical displays. The advantage offered by full color electro-optical displays is the ability to use computer generated imagery to present pictorial formats and color-coded information. By using these coding techniques, information can be presented to the pilot in a simplified form which is easier to understand and interpret and, therefore, more efficient.

SECTION II

PURPOSE

The primary purpose of this study was to determine the feasibility of applying pictorial and color coding techniques to a stores display which presents information to the pilot pertaining to the status (e.g., master arm states, fuzing, interval, etc.) of stores that are being carried by the aircraft. This display was chosen for evaluation since prior combat experience (i.e., Vietnam) has shown that errors can be made during attacks that result in the failure to deliver weapons properly. These errors were mainly due to the complexity of stores management systems in current fighter aircraft. Current systems make it difficult for the pilot to determine the status of the stores on the aircraft from the multitude of controls and indicators on the stores management panels (Figure 1). Therefore, it was felt that by designing a format to present intuitive stores status information in one location, a high payoff in mission success could be realized.

1. TEST OBJECTIVES

Four methods for presenting stores status information on a CRT were evaluated to determine which is best in terms of pilot performance:

1) alphanumeric format
2) monochrome pictorial format
3) color pictorial format
4) both alphanumeric and color pictorial format.

The alphanumeric format was chosen for evaluation because the capability to present alphanumeric information is within the state of the art (e.g. F-16 and F-18). The monochrome pictorial format was chosen to investigate the feasibility of pictorially coding information through the use of CGI. The color pictorial format was chosen to investigate the additional use of color coding because the beneficial effects of color coding tend to be contextually dependent (Reference 1). And finally, the color pictorial and alphanumeric formats were used together to determine the effectiveness of using both formats concurrently.

Another objective of this study was to investigate four methods (2 color and 2 monochrome) of indicating switch selections on a multifunction

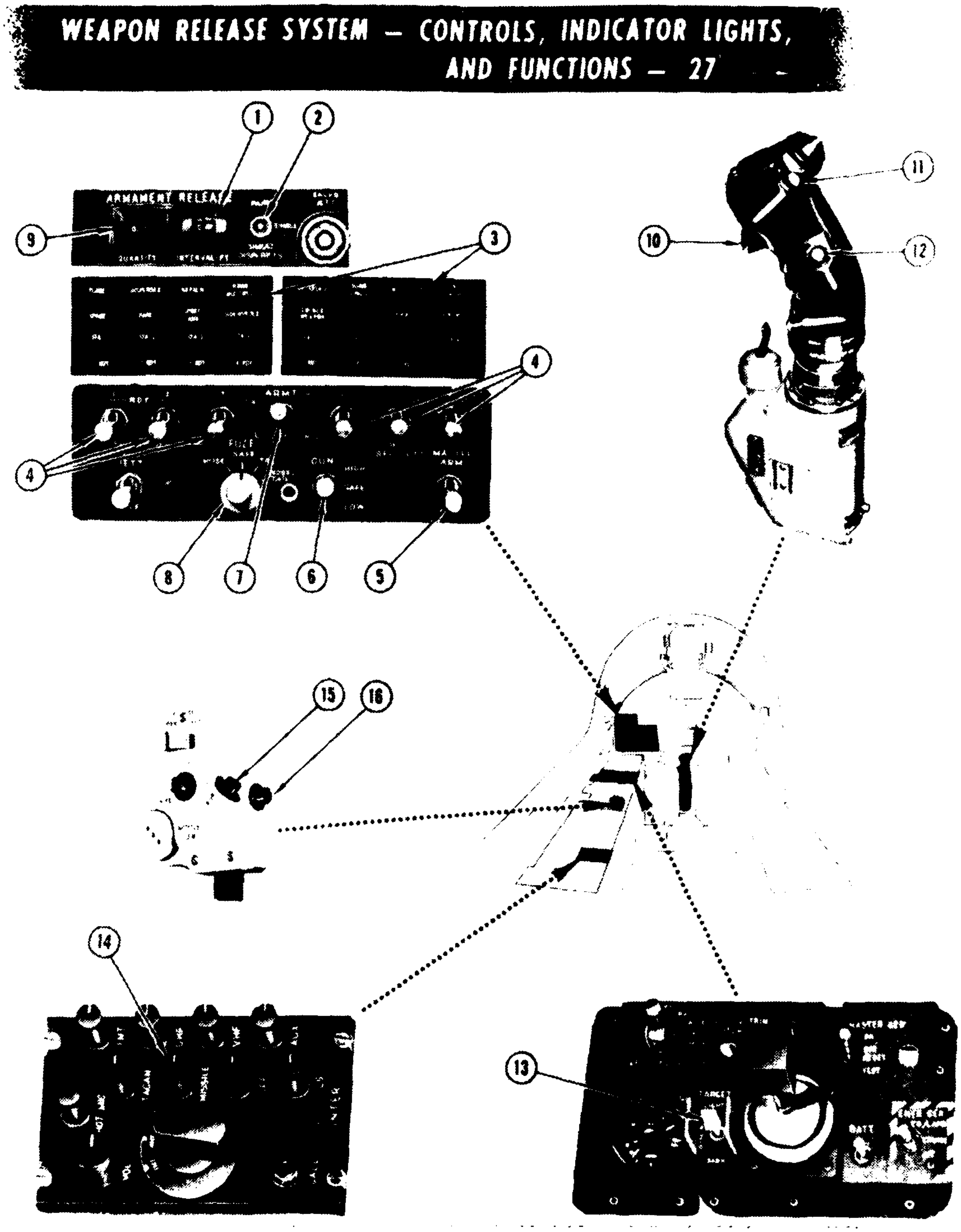


Figure 1. A-7D Weapons Release System

control (MFC) which activate the digital entry keyboard (DEK) and aircraft subsystems (Table 1). In addition, the acceptability of displaying systems status information on the MFC was examined.

TABLE 1

MFC SWITCH STATUS CODES

	INDICATES SWITCH SELECTIONS THAT ACTIVATE THE DEK	INDICATES SWITCH SELECTIONS THAT ACTIVATE AIRCRAFT SUBSYSTEMS
	Monochrome	
METHOD 1:	Black legend on white field	Black legend on white field
METHOD 2:	Black legend on white field	Legend in white box
	Color	
METHOD 3:	Black legend on green field	Legend in green
METHOD 4:	Green cursor by white legend	Legend in green

SECTION III

APPARATUS

A single-place cockpit simulator of A-7 geometry containing electro-optical displays and a multifunction control was utilized for the evaluation (Figure 2). Four electro-optical displays presented information to the pilot. The Head-Up Display (HUD), supplied, in the pilots forward field of view, flight control information, weapons symbology, and readouts of the MFC legends corresponding to the selected MFC switches and digits (Figure 3, see Appendix A for more details). The pictorial stores status formats displayed information pertaining to stores onboard the aircraft and were presented on the CRT in the upper left. The alphanumeric stores status format appeared in the center of the MFC. Various systems onboard the aircraft were also controlled and monitored through the MFC. Conventional electro-mechanical instruments located on the upper right of the instrument panel presented engine status information for the following parameters: fuel flow, turbine outlet temperature (TOT), revolutions per minute (RPM), and oil pressure. Only the fuel flow, TOT, and RPM parameters were updated to show status and trend. During testing, the canopy of the simulator was covered to help eliminate distractions to the pilot.

1. STORES STATUS FORMATS (SSF)

Four methods for presenting stores information were examined. In each method at least the following information was presented: electronic countermeasures (ECM) pod status, external fuel tank status, and parameters for a selected weapon option (e.g., for a Mark 82 weapon type, quantity, interval, fuzing, drop mode, stations, master arm status, and hung bomb status would be presented). In one method, only alphanumeric stores data appeared on the MFC. In two other methods, pictorial stores data (one monochrome and one color) were presented on the CRT in the upper left. In a fourth method, both alphanumeric stores data on the MFC and color pictorial stores data on the CRT in the upper left were presented. The methods for presenting stores information are described in more detail below.

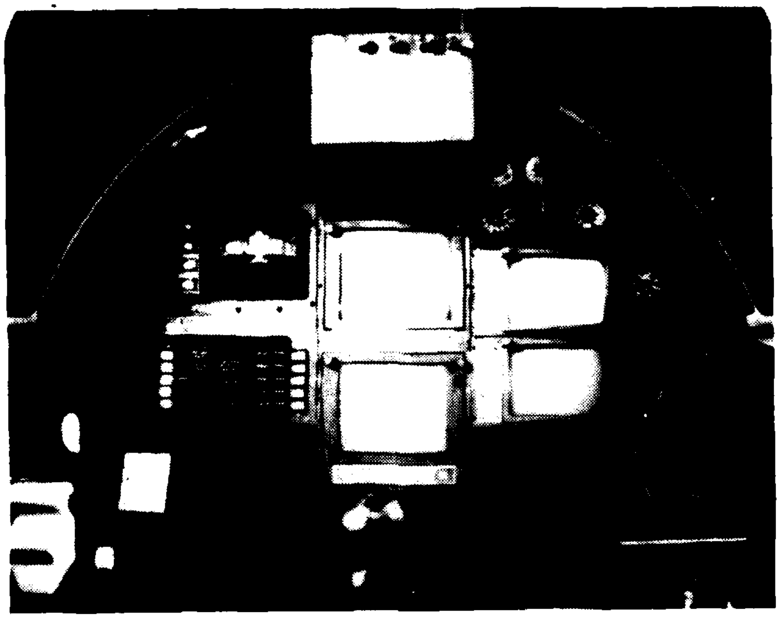


Figure 2. Cockpit Simulator

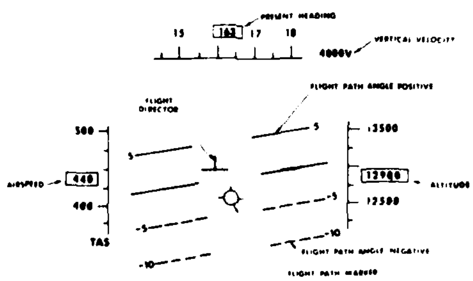


Figure 3. Head-Up Display Format

a. Alphanumeric Stores Format

One format consisted entirely of alphanumeric stores information presented on the MFC (Figure 4). Since both monochrome and color switch status codes were being evaluated on the MFC (Table 1), the alphanumeric stores format was either monochrome or color depending upon which switch status code was being used. Information for four weapon options was shown in the legends of the upper four switches on the right hand side of the MFC. Information pertaining to the currently selected weapon option was shown in a switch legend and in the center column of the MFC. Other stores data was also presented in the center column of the MFC (e.g., EXT FUEL ON or ECM ON).

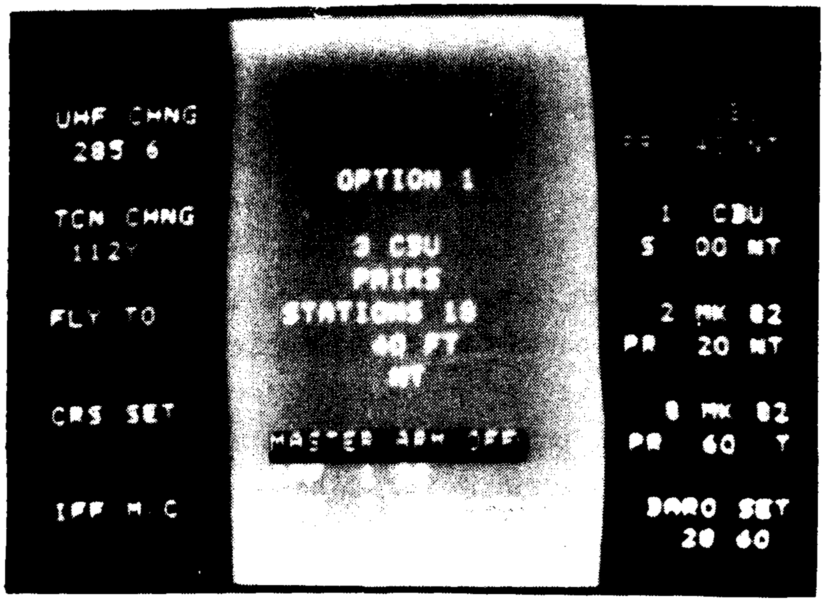


Figure 4. Alphanumeric Stores Format

Store type was denoted by alphanumeric abbreviations (MK 82 for Mark 82, CBU for cluster bomb unit, BLU for Napalm tank, and ECM for electronic countermeasure pod). If an abbreviation was not presented, the corresponding store type was not programmed for a weapon option. The store quantity was shown by numbers preceding the weapon types (e.g., 12 MK 82). Only the quantity of weapons programmed for each weapon option was presented. Selected stations were shown by alphanumerics in the center of the MFC (e.g., STATIONS 2 8). Only station information for the currently selected weapon option was presented.

Selection of a weapon option was shown by the presence of one of the MFC switch status codes (depending upon the method being evaluated) and weapon option information in the center column of the MFC. Release of a weapon option was shown by the absence of an MFC switch status code, updated information in the MFC switch legends, and the absence of the weapon option information in the center of the MFC. A hung bomb condition was indicated by a message noting at which station the release had malfunctioned (e.g., HUNG STA 2). This message was in red in the MFC color format and flashed at a rate of 2 Hz in the MFC monochrome format. Master arm switch position was indicated by one of three MFC messages: 1) MASTER ARM OFF (this message appeared if the option was selected and the master arm was in the off position; the message was yellow in the color format), 2) MASTER ARM ON (this message appeared if there was a hung store and the master arm was still on. The message was red in the color format and flashed in the monochrome format; the message also appeared if the master arm was on but other parameters of a selected option were not satisfied. The message was yellow in the color format), or 3) SYSTEM READY (this message appeared if the option was selected, armed, and ready for release; the message was green in the color format).

The status of ECM pods and fuel tanks (on or off) were presented in the center column of the MFC by alphanumerics (e.g., EXT FUEL ON or ECM ON). The drop mode (number of stores released per pickle button activation) was indicated both in the MFC center column and switch legends by abbreviations (e.g., SNGL (single), PR (pair), and SALVO (simultaneous)).

The interval (in feet) between weapon impact points was shown by alphanumerics (e.g., 30 FT). Generally, intervals greater than 0

indicated the delivery would be a ripple release. Two cases where specifying the interval parameter was not appropriate were when:

(1) selected store quantity was one, and

(2) selected store quantity was two with pairs drop mode selected.

In these cases the displayed interval was 0 FT. Weapon fuzing information was presented by the letters N (nose fuzing) and T (tail fuzing). (For the purposes of this study, it was assumed that BLUs and CBUs are automatically fuzed.)

b. Pictorial Stores Format

Two formats, monochrome and color, presented pictorial stores information on the CRT in the upper left (Figure 5). (No alphanumeric stores information appeared on the MFC. For example, the legends on the four upper right switches of the MFC were Option 1, 2, 3, and 4, respectively.) Both pictorial formats presented information pertaining to all the stores onboard the aircraft and pertaining to the currently selected weapon option. The formats consisted of a white planform against a darker background (gray in monochrome format and blue in color format). Shapes on the planform represented the stores onboard the aircraft. These shapes will be referred to as storeforms.

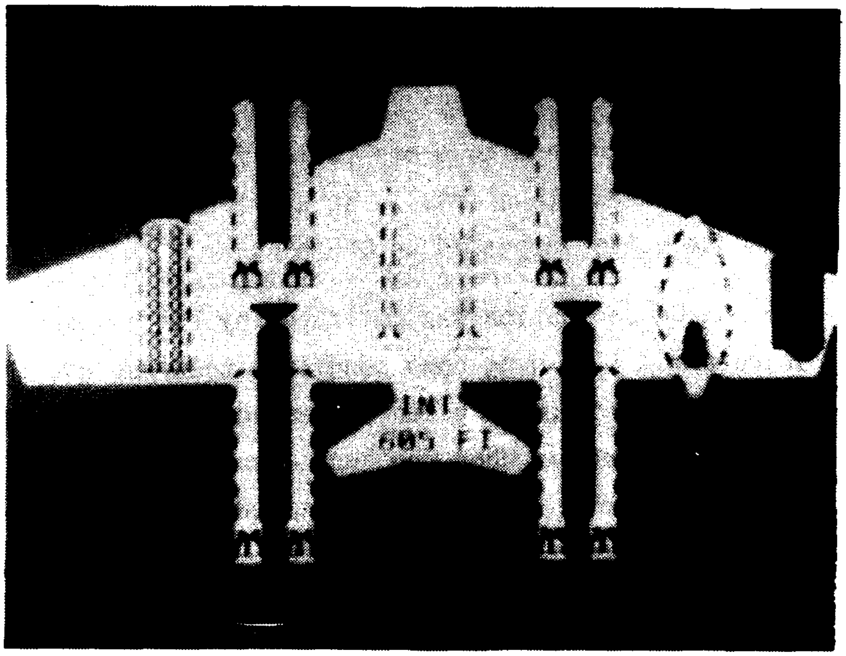


Figure 5. Pictorial Stores Format

Store type was denoted by the shape of the storeform. Oval forms with five small circles inside depicted fuel tanks. Napalm tanks were depicted by oval forms containing a flame (blue outlined in yellow in the color format). Forms which were rectangular in shape and filled with two columns of small circles represented CBUs. The forms for ECM pods had jagged lines representing lightning bolts either inside (pods not selected) or outside (pods selected). Both the MK 82s and AIM 9s were depicted by narrow rectangular forms with distinct noses and tails, with the AIM 9 forms smaller.

Store quantity was shown by the number of storeforms on the planform. The station from which selected weapons would be delivered for a selected option was indicated by the locations of the storeform on the planform.

If a storeform had not been selected as part of a weapon delivery option, the storeform was outlined in dashed lines in both the monochrome and color formats. If a storeform had been selected, the storeform was outlined in solid lines in both the monochrome and color format and was also shaded in the color format. (Only the center portion of the MK 82 storeforms was shaded.) The following shades were used to denote selection in the color format: ECM pods--green; fuel tanks--tan; CBUs, BLUs, AIM-9s, and MK 82s--yellow. Activation of the master arm switch was indicated by shading the storeform black (monochrome format) or changing the color of the storeform to green (color format; only the center was shaded on the MK 82 storeforms). No alphanumeric message concerning master arm selection appeared on the MFC.

Release of the weapon option was indicated by the absence of the appropriate storeform. If a hung bomb condition occurred and the master arm was on, the appropriate hung store flashed (monochrome format) or was shaded red (color format). When the hung weapon was defused, the fuzing code was removed. After deselection of the master arm switch in the monochrome format, the hung stores was unshaded, outlined in solid lines, and had a message (i.e., HUNG) presented vertically and overwriting the center of the storeform. In the color format, the storeforms was outlined in red. If the option had been deselected, the hung store was outlined in dashed lines, and in the monochrome format a HUNG message

was overwritten vertically in the center of the storeform; in the color format the storeform was outlined in dashed red lines and the center was shaded yellow.

Weapon drop mode was indicated on both the monochrome and color formats for the selected weapon option by the arrowhead pointing to the nose of the appropriate storeform. In the color format, the arrowheads were the same color as the corresponding storeforms. (In the case of MK 82s, they were the same color as the center of the storeform.)

Interval (in feet) for the selected weapon option was shown in both pictorial formats by alphanumerics on the tail of the planform (e.g., INT 75 FT). Generally, intervals greater than 0 indicated the delivery would be a ripple release. Two cases where specifying the interval parameter was not appropriate were when:

(1) selected store quantity was one, and

(2) selected store quantity was two with pairs drop mode selected.

In these cases the displayed interval was INT 0.

Weapon fuzing for selected MK 82 options was indicated by shading the nose and/or tail section of the storeform with black (monochrome format) or green (color format). (For the purposes of this study, it was assumed that BLUs and CBUs are automatically fuzed.)

c. Alphanumeric Pictorial Stores Format

In one condition both alphanumeric stores data on the MFC and color pictorial stores data on the upper left CRT were presented. This was done to investigate the effectiveness of using both formats concurrently.

2. MULTIFUNCTION CONTROL (MFC)

a. MFC Hardware

The MFC hardware was located on the left front instrument panel. It consisted of eight dedicated push button system select switches in a row across the top of the CRT and ten push button multifunction switches mounted in columns on the left and right sides of the CRT (Figure 6). Seven of the dedicated system select switches had legends displayed on the switch faces, but only three of these were active. For the ten

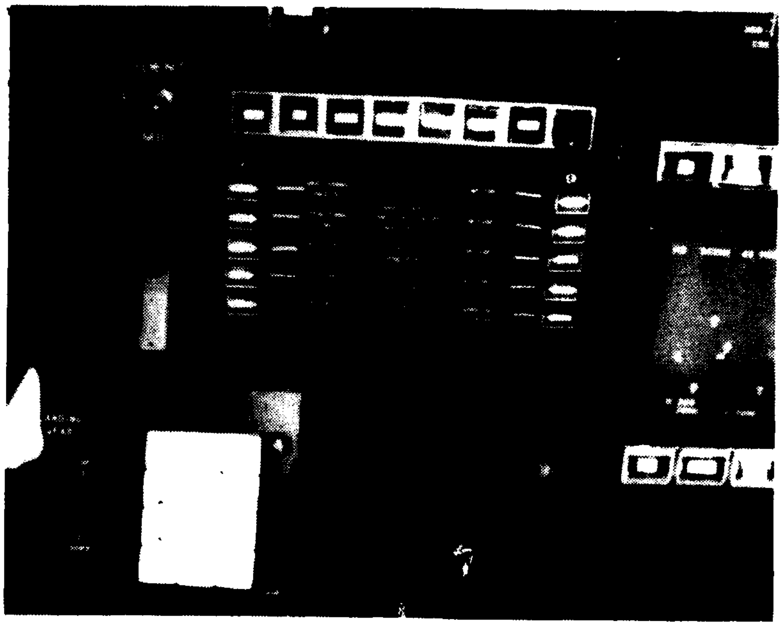


Figure 6. Multifunction Control Hardware

multifunction switches, the legends were displayed adjacent to each switch and changed according to the function the switch was serving. These switches were active only when a legend was displayed adjacent to the switch and when the experimenter initiated a task. The switches remained active until task completion. The data entry keyboard (DEK), located on the left console, became operable and lighted when the pilot was required to select and enter digits. Once the ENTER key was selected, the DEK became inactive and unlighted. The DEK consisted of 12 dedicated push button keys arranged in a 4 row x 3 column telephone layout with the CLEAR and ENTER keys on the left and right sides of the zero, respectively. For some tasks, the letters X and Y could be selected on the keys labeled 7 and 9, respectively.

b. MFC Switch Status Codes

Four methods (2 color and 2 monochrome) of indicating switch selections which activate the DEK and aircraft subsystems were examined (Table 1). The status codes indicating switch selections which activate the DEK were presented only while the DEK was active. The codes indicating switch selections which activate aircraft subsystems were presented whenever the subsystems were engaged. Appendix B describes the MFC tasks

used in this study and when the switch status codes for DEK activation and subsystem activation were presented.

c. MFC Systems Status Format

The feasibility of displaying systems status information on the MFC was also subjectively evaluated during this study. The benefit derived from using the MFC, rather than a separate CRT, is that systems status information can be presented in closer proximity to the systems' controls.

Figure 6 shows what the MFC, with status information located between the two lines, looked like in this study. When the color MFC was used, the status area had white characters on a blue background. The blue background was used to clearly depict the area dedicated to status information and ensure separation from the MFC switch legends. When the (monochrome) MFC was used, the status area had white characters on a black background. Vertical white lines were used to clearly separate the status area from the MFC switch legends.

Appendix C contains a detailed description of the status format for the CCIP flight mode used in this study. The status format was not presented when alphanumeric stores status information was being displayed on the MFC.

d. MFC Logic

Two types of MFC logic were used in this study--tailored and branching. In tailored control logic, the ten most commonly used functions for the current flight mode are assigned to the switches. In contrast, the options for only one system are presented on the MFC with branching logic. The tasks commonly required in a flight mode can be completed more rapidly using tailored logic compared to branching logic since fewer switch hits are required. The branching and tailoring logics were implemented concurrently in the present study. The tailored logic was used as the primary logic and the branching logic was used to access infrequently used functions not available on the tailored logic page. Each task was initiated with the CCIP tailored page on the MFC (Figure 6). (The legends for the four upper right switches were Option 1, 2, 3, and 4, respectively, unless a stores task had been initiated and the

alphanumeric stores format was to be displayed.) All but one of the tasks given to the pilots could be completed using the tailored logic and all tasks could be completed using the branching logic. The IFF status (Normal, Low, or Standby) task could not be accomplished using the tailored page and required selection of the branching logic.

The MFC tasks used in the present study are shown in Table 2. Completion of each task required a particular operating sequence on the MFC or MFC and DEK. A brief description of each operating sequence is contained in Appendix B.

TABLE 2

MFC TASKS

TASK	NUMBER PER MISSION
1) Set UHF frequency	1
2) Change IFF Mode 1	1
3) Change IFF Mode 3	1
*4) Change IFF NORMAL/LOW/STDBY/State	1
5) Change TACAN channel	1
6) Engage FLY TO function to previous setting	1
7) Change FLY TO setting	1
8) Disengage FLY TO function	1
TOTAL	8

*In the current study, the task could only be completed by using the branching logic.

When branching control logic was used, the MFC returned to the CCIP tailored page after:

(1) Selection of the CCIP flight mode switch.

(2) Ten seconds had elapsed since the selection of ENTER on the DEK.

(3) Ten seconds had elapsed since the selection of an MFC switch which did not activate the DEK (e.g., NORMAL/LOW/STANDBY switch). (The logic did not revert whenever the DEK was active.)

3. DEDICATED CONTROLS

The following dedicated controls were operable and available for use by the pilot throughout testing: center stick, trim button on the stick, throttle, rudders, and a three position HUD symbology declutter switch. The store release button on the stick was operable during the pop-up maneuver.

4. EXPERIMENTERS' CONSOLE

The experimenters' console provided the experimenters with:

(1) repeater displays of the displays in the cockpit;

(2) a display of the current experimental status; and

(3) the capability to control the simulation, initiate tasks and record data. For more information on the experimenters' console, see Appendix D.

SECTION IV

METHOD

1. TEST DESIGN

Performance for each pilot was observed under each of the four stores formats and MFC switch status codes. The pilots flew one 30 minute flight with each of the stores formats and MFC switch status methods, making a total of four test flights for each pilot. The stores format and MFC switch status method to be examined in each flight was balanced such that four pilots received each possible combination. (The order in which the pilots flew each condition is contained in Appendix E, Tables E1 and E2.) The order was determined by the use of balanced Latin square design so that a flight with any one configuration was preceded equally often by each of the other configurations.

2. SUBJECTS

A total of 16 Air National Guard A-7D pilots served as subjects. The pilots had a mean of 2553 flying hours.

3. SIMULATION FLIGHTS

A total of four training missions and eight data missions were used. All pilots flew the four training missions; and pilots 1-8 flew data missions 1-4, and pilots 9-16 flew data missions 5-8. The order in which each pilot flew the missions was balanced such that each mission was flown an equal number of times with each stores format. During the training and data missions, the pilots received one of each type of MFC and stores task. The data mission tasks were identical to the training mission tasks except that the correct responses to the tasks were different. The task order was also different across missions and was randomly determined within the following constraint: the FLY TO engage task had to occur prior to the FLY TO change task which had to occur prior to the FLY TO disengage task.

a. Stores Information Retrieval Tasks

Eight different stores questions were used in this study. The questions pertained to store type, quantity, interval, fuzing, stations,

drop mode, system status (master arm or ECM selection) and hung bomb status (Table 3). Each pilot had one of each question per mission. The stores load from which the pilot answered the questions was changed for each question (Appendix E, Table E3). A total of 16 loads was used: eight loads for data missions and eight loads for training missions. Four load complexity levels were also examined. Load complexity levels 1, 2, 3, and 4 consisted of 2, 3, 4, and 5 store types, respectively. The store types and parameters assigned to each load (for the data and training missions) are shown in Figures 7 and 8. The number of pilots having each load/question type combination was equal; 8 in data missions and 16 in training missions. Each load/question type combination also occurred with each stores format two times since each mission was flown an equal number of times with each stores format.

TABLE 3

STORES QUESTIONS

TYPE -- What type of store is selected?

QUANTITY -- How many stores are selected?

INTERVAL -- What interval do you have selected?

FUZING -- What fuzing do you have selected?

STATIONS -- Which station or stations do you have selected?

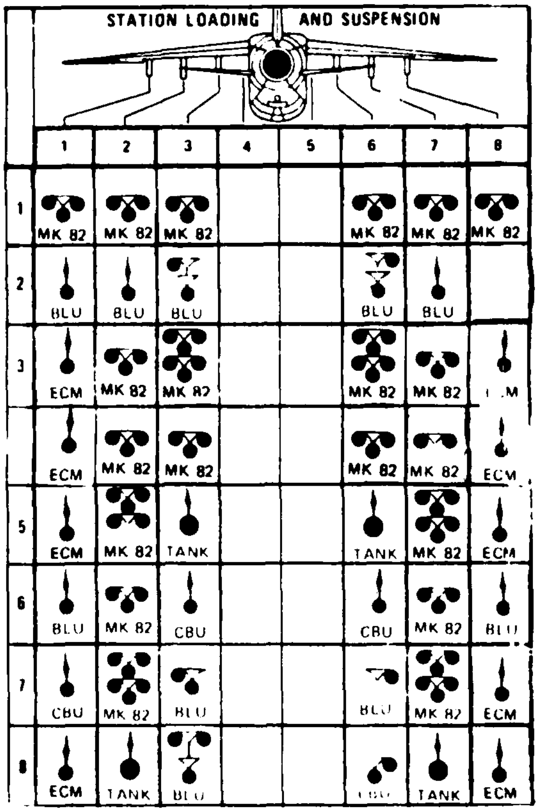
DROP MODE -- What's your drop mode?

STATUS I -- What's the status of your master arm switch?
(Loads 1, 2, 6, 7)
or
What's your ECM status? (Loads 3, 4, 5, 8)

STATUS II -- Do you have any hung stores?

b. MFC Tasks

Each pilot completed eight MFC operations per flight. The task types and steps to perform the tasks are described in Appendix B.



18 MK 82s, PRS, STA 123678, 30 FT, N/T, M/A ON (release arrows at STA 18)

3 BLUs, PRS, STA 36, 30 FT, M/A ON, HUNG STA 3 RC (STA 2, 7, and 6 RC blank, release arrows at STA 6 FR and 3 RC, hung code at STA 3

3 CBUs, PRS, STA 18, 40 FT, M/A OFF, HUNG STA 8 C (STA 1 C blank, release arrows at STA 1 L and STA 8 C, hung code at STA 8 C)

6 MK 82s, SN, STA 1278, 50 FT, N, M/A OFF, ECM OFF (release arrow at STA 1)

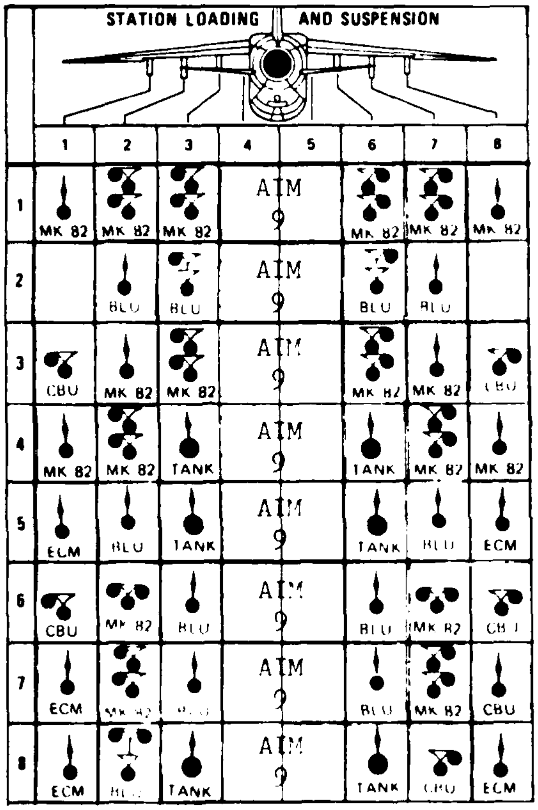
2 BLUs, SN, STA 27, 30 FT, M/A ON, ECM ON, FUEL ON (release arrow at STA 2)

1 CBU, SN, STA 8, M/A ON, HUNG STA 8 (STA 1 blank, STA 8 C blank, release arrow at STA 8 R, hung code at STA 8 R)

7 MK 82s, PRS, STA 27, 40 FT, T, M/A OFF, HUNG STA 7 RC, ECM OFF (STA 2 RC blank release arrows at STA 2 FC and 7 RC, hung code at STA 7 RC)

1 BLU, SN, STA 2, M/A ON, ECM ON, FUEL ON

Figure 7. Data Mission Bomb Loads



12 MK 82s, SALVO, STA 2367 (4 TERS), 50 FT, N/T, M/A ON (release arrows at all 12 bombs)

3 BLUs, PRS, STA 127, 20 FT, M/A ON, HUNG STA 1 (STA 8 blank, release arrows at STA 17, hung code at STA 1)

6 MK 82s, SN, STA 27 (2 TERS), 40 FT, N, M/A OFF, ECM OFF (release arrow STA 2, center bomb)

5 MK 82s, PRS, STA 27 (2 TERS), 55 FT, N/T, M/A ON, HUNG STA 2 LC, ECM (STA 7C blank, release arrows STA 2C and STA 7R, hung code at STA 2C)

3 MK 82s, PRS, STA 27 (2 MERS), 60 FT, T, M/A ON, HUNG STA 7 RC, ECM ON, FUEL ON STA 2 RC blank, release arrows STA 2 FC and STA 7 RC, hung code at STA 7 RC)

2 s, SN, STA 36, 100 FT, M/A OFF (release arrow at STA 3)

3 BLUs, PRS, STA 36, 0 FT, M/A OFF, HUNG STA 3, ECM OFF (STA 6C blank, release arrows STA 3C & STA 6R, hung code STA 3)

1 CBU, SN, STA 6, M/A ON, ECM OFF, FUEL ON (release arrow at STA 6)

Figure 8. Training Mission Bomb Loads

4. PROCEDURES

a. Pilot Briefing

Throughout the briefing and training phases of the experiment, the procedures were standardized such that each pilot received the same infomation and opportunity for familiarization with the formats, MFC logic, cockpit simulator, and procedures. Initial briefings were conducted at the pilot's home base prior to their participation in the testing. After familiarizing the pilots with the advanced "digital" airplane cockpit concept, the experimenters explained the controls, displays, and procedures to be used in the current study. The subjects were also given study materials describing the MFC logic in order to familiarize themselves with the operating sequence of each type of task to be presented during the test flights.

Each pilot received an on-site cockpit simulator briefing on the day of testing. (See Appendix F for the daily test schedule.) The information explained or demonstrated during this briefing included:

(1) Symbology and dynamics of the display formats
(2) Stores formats to be evaluated
(3) Status indications for each store type
(4) MFC operation and operating sequence of the keyboard logic for each type of task to be completed
(5) Switch status codes to be evaluated
(6) Pre-entry readout, error messages, and status information
(7) Correction procedures after entering the wrong digits or incorrectly progressing through the logic level steps
(8) Pilot's tasks
(9) Procedural instructions, and
(10) Use of rudders, stick, throttle, stick switches, flight mode switches, intercom system, brightness controls, and flight plan (modified AF Form 70s).

b. Training and Data Missions

Immediately before each data flight, a simulation training flight was conducted to give the pilot experience with the handling qualities of the simulator and operational procedures of the test conditions. The

training flights were identical to the data flights in terms of the flight conditions and the types of stores and MFC tasks. Mission scripts were constructed around each set of tasks to provide external realism (Appendix G). The task instructions were given over a headset using standard controller terminology.

Throughout each flight, the symbology and information displayed on the HUD was dynamic in response to thrust, bank, and pitch inputs. The ground tracks did not involve any turns but did include elevation changes to simulate terrain following flight. The pilot's flying task was to keep the velocity vector symbol centered on the flight director and to maintain 420 knots calibrated airspeed (KCAS). Each flight took approximately 20 minutes to complete.

Besides the flying task, each pilot was also required to complete communication and navigation tasks using the MFC and report stores status. The fact that performance for all tasks (flying, MFC data entry, and information retrieval from stores formats) was to be recorded was stressed to the pilots.

c. Task Administration

Task administration was controlled from the experimenters' console. Each task consisted of three time periods described below. For each task, flight performance response time, and MFC task accuracy were recorded automatically by the computer; however, an experimenter had to input the stores task response on the computer terminal.

The experimenter pushed a PRE-TASK switch on the console which started a 15 second timer; a second push would restart the timer. Activation of this switch automatically started the recording of baseline flight performance.

Once the 15 second pre-task period of baseline performance had been recorded, an experimenter read either a stores question or an MFC task over the headset using standard controller terminology. The pilot was required to make a verbal response indicating that he understood the instruction before an experimenter initiated a task and data recording. (Using these procedures, time to give the instruction was not a part of the pre-task or task time.)

1) Stores Format Task Administration

Concurrent with the pilot's acknowledgement of the instructions, an experimenter pushed the TASK switch on the console to initiate the task. Once the TASK switch was activated, the following occurred:

(1) Information for a new load appropriate for that question was displayed via the stores format being evaluated
(2) A 30-second timer was started
(3) Recording of flight parameters and response time began
(4) Time elapsed into the task was displayed on the experimenters' console status monitor, as well as question type, correct response, etc.

The computer was programmed to allow 30 seconds for task completion after the activation of the task switch. All pilots completed the tasks within the 30 second period and only the pilot's first answer to the stores question was recorded. If the pilot made an error, an experimenter told him the correct response. This prompted the pilot to provide valuable information on which aspect of the format symbology he had mistaken or overlooked.

Once the TASK ABORT switch was pushed or the 30 seconds had elapsed, data recording stopped. An experimenter recorded the pilot's response via the computer terminal. Indexes of the accuracy of the pilot's response in relationship to the information programmed for that particular stores task was automatically computed and recorded by the computer. (A tape recording of each flight was made in case the pilot's response was questionable). When an experimenter hit the PRE-TASK switch for the following task, the stores format was removed. (In the formats where stores data was presented on the MFC, the legends for the four upper right became Option 1, 2, 3, and 4, and the stores data in the center column was removed.)

2) MFC Task Administration

Immediately after the pilot acknowledged the MFC instructions, the experimenter pushed the TASK switch to initiate the task. Activation of the TASK switch initiated recording of flight performance and keyboard operation measures and unlocked the MFC. The

unlocking of the MFC enabled the pilot to select the appropriate switches required for the task.

The information required by the pilot to complete the MFC tasks was provided on modified Flight Plans (AF Form 70s, Figure 9) and was referenced during the instructions by the corresponding letter. The following was identified by a letter on Form 70: UHF frequencies, IFF codes, altimeter settings, TACAN channels, and waypoint identifiers. By identifying information in this way, errors due to misunderstanding or forgetting were minimized.

Due to time constraints, only the switches required for the tasks to be used in this experiment were programmed. If the pilot selected a switch that was unprogrammed, the legend "OPTION N/A" was displayed. The legend disappeared with the next programmed MFC switch hit. Mistakes made by pushing an inappropriate switch were corrected either by selecting the correct switch if it was available on the same page, or pushing either the RETURN, function select switch, or CCIP flight mode switch to bring up the page having the correct switch.

Once the pilot had progressed through the MFC logic to the switch action that activated the DEK, a pre-entry readout of each digit selected was displayed to the pilot on the MFC and HUD. When the pilot selected the last digit required for the task, the pre-entry readout flashed until the pilot pushed the ENTER key. The pre-entry readout provided the pilot with the capability to verify that the digits selected were accurate. If the pilot made an error that was in the appropriate range or realistic for the task (example: 236.7 instead of 236.6 UHF frequency), the pre-entry readout indicated the incorrect frequency (pre-entry = 236.7). In order to correct the mistake, the pilot had to clear the incorrect digit. One push of the CLEAR key on the DEK erased the last selected digit; two pushes of the CLEAR key erased all the digits selected.

An error message was displayed to the pilot when an error was made that was out of the appropriate range or unrealistic for a task. For example, if 9 was selected for the first IFF code digit for mode 3, the message BAD DATA was displayed to the pilot since the first digit can be no larger than 7. This message was yellow when the color

D 1 & 5	PILOT'S FLIGHT PLAN AND FLIGHT LOG				
ARTC FREQ	A 275.8	D 111X	G 62	J 2400	M 2
	B 348.0	E 116Y	H 51	K 2100	N 3
	C 364.3	F 125Y	I 43	L 3600	O 4

AIRCRAFT IDENT	TAKE-OFF TIME	TOTAL DISTANCE	TOTAL ETE	TOTAL AMT FUEL
BARFLY 11		245	35.0	

	IDENT / FREQ	MAG CRS	DISTANCE / REMAIN	GROUND SPEED	ETE / REMAIN	ETA / ATA	LEG / REMAIN	ACTUAL FUEL REMAIN
4945.00 N								
0633.00 E								
5053.00 N		072°	245			35.0		
1239.00 E			-			-		

AF FORM MAY 68 70

Figure 9. AF Form 70

switch status codes were being evaluated. The actual illegal digit never appeared on the pre-entry readout, but was ignored by the computer. When the pilot made a legal switch hit on the DEK, the BAD DATA message disappeared.

In the case where the pilot pushed too many legal digits, the message CHECK DATA was displayed and the pre-entry readout remained (except the surplus digits were ignored by the computer). This message was yellow when the color switch status codes were being evaluated. If the remaining selected digits were the desired entry, the pilot would push the ENTER button. If the desired entry was 6606 instead of 6600, however, the pilot would have to operate the CLEAR function to erase the 0 and select 6 in order to complete the task event correctly. The CHECK DATA message disappeared with the first hit of the CLEAR or ENTER key.

The pre-entry readout and various messages described in the previous section only pertain to keyboard operation prior to actual completion of a task. An exception to this occurred if the pilot entered too few legal digits (example: 236 for 236.7 UHF frequency). The MFC and DEK remained active and the message RE-ENTER DATA was displayed. This message was yellow when the color switch status codes were being evaluated. The pilot's first MFC or DEK switch hit of the reentry initiated the recording of data and erased the message.

The majority of tasks to be used were considered complete once the pilot selected the ENTER key on the DEK. (Exceptions are noted in Appendix B). Once an MFC task was completed, whether it was correct or incorrect, all recording of data was stopped. The computer then checked to see if the data selections and entry were the same as the information programmed for the task. The following describes the MFC configuration and operating procedures after the computer determined whether the completed task was incorrect or correct:

If a task was completed incorrectly, the pilot was required to repeat it. The task error appeared on the experimenters' status display and the pilot's MFC was locked with the last page used before task completion displayed. After the pilot was notified by an experimenter that an error had been made and the pilot responded that he

understood, the experimenter pushed the KEYBOARD UNLOCK switch which unlocked the MFC. The pilot then began to repeat the task with the first switch hit on the MFC initiating data recording.

d. Mission Termination

Prior to terminating the mission, an experimenter verified that the performance on each task was recorded properly (i.e., the simulation did not malfunction). If not, the capability existed to record data for any single task without rerunning the whole data flight.

After the pilot completed all the required tasks for the mission successfully and the performance data was recorded properly, an experimenter terminated the flight by pushing the MISSION COMPLETE switch on the console. After a flight had been terminated, a summary statistics program was run to reduce all the data that had been recorded.

e. Debriefing

Immediately after each flight the pilot was given a questionnaire (Apendix H) concerned with the stores format and MFC switch status codes evaluated during that flight. The final debriefing questionnaire was administered following the completion of all data flights and was designed to elicit subjective evaluation of the stores formats, MFC operation and switch status codes, other flight displays, and simulation quality.

5. PERFORMANCE MEASURES

a. Flight Data

The pilots' performance in terms of flying the simulator, reporting stores status, and performing MFC tasks was recorded on magnetic tape. The following flight parameters were recorded ten times per second:

(1) Vertical steering error (pixels)
(2) Horizontal steering error (pixels)
(3) Airspeed error (knots).

An rms error score was computed on these flight parameters for two time periods:

(1) Fifteen second period prior to each stores and MFC task (pre-task period), and

(2) Time period required to complete each stores and MFC task.

To measure the effect of retrieving information from the stores formats or completing operations on the MFC on the pilot's flying performance, the baseline flight performance recorded during the pre-task period was subtracted from the performance during the tasks. In other words, rms error for the pre-task period for each parameter was subtracted from the rms error computed for the task period.

b. Stores Task Data

Stores task performance was evaluated by recording:

(1) Response time (elapsed time from TASK switch activation to TASK ABORT switch activation)

(2) Pilot's response.

c. MFC Task Data

The following MFC related data was recorded:

(1) Number of switch hits made.

(2) Minimum number of switch hits required to complete a task.

(3) Number of hits made minus minimum number of switch hits required.

(4) Number of times MFC reverted to CCIP tailored page.

(5) Elapsed time from activation of TASK switch to task completion or TASK ABORT.

6. DATA ANALYSIS

The data (flight performance and task time) was analyzed by multivariate analysis of variance (MANOVA) using the Statistical Package for the Social Sciences (SPSS) (Reference 2). To further examine significant performance differences, the Krishnaiah Finite Intersection Test (FIT), a simultaneous comparison test for multivariate data, was utilized (Reference 3). Kolmogorov-Smirnov tests were performed on the subjective questionnaire data (Reference 4).

SECTION V

RESULTS

1. STORES FORMATS

To decrease the complexity of the data analyses, the data for the stores tasks were collapsed into two groups, single storeform search (i.e., inspection of one storeform provides the information required, such as fuzing) and multiple storeform search (i.e., quantity), and a MANOVA was run to determine if pilot performance differed among the four store formats and two groups of information retrieval tasks. The results indicated a significant difference among the store formats (F (12, 132) = 3.07, p = 0.0008) and between the two groups of information retrieval tasks (F (4, 12) = 4.52, p = 0.019). There was no significant interaction effect (F (12, 132) = 1.07, p = .389). According to the FIT analyses, response time was the dependent variable most sensitive to changes in the levels of the independent variables. More specifically, the FIT analyses showed that there were no significant performance differences among the color pictorial, alphanumeric, and color pictorial/alphanumeric stores formats; however, a significant difference between these three formats and the black and white pictorial format was found (F (1, 505) = 12.667, $p < 0.05$; F (1, 505) = 43.217, $p < 0.05$; and F (1, 505) = 14.096, $p < 0.05$, respectively). Figure 10 shows a graph of the mean response time for each store format condition. The mean response times for single storeform search and multiple storeform search were 4.00 and 4.78 seconds, respectively.

Another MANOVA was run to investigate the differences among the store formats as a function of four complexity levels of the information presented. The four complexity levels were defined as follows: load complexity levels 1, 2, 3, and 4 consisted of 2, 3, 4, and 5 different store types, respectively. The results of this MANOVA indicated no significant performance differences among the complexity levels (F < 1.0).

Separate analysis of the error data indicated a significant difference among the number of errors committed with each store format (X^2 (3) = 7.88, $p < 0.05$). The alphanumeric format had the lowest number of errors (three) and the black and white, color, and alphanumeric/color formats had 15, 13, and 12 errors, respectively.

On the debriefing questionnaire, pilots were asked to compare, using a five-point scale, the four store formats and conventional electro-mechanical indicators. The results indicated significant pilot preference for the combination of alphanumeric and color pictorial formats ($\underline{D}$ = .675, $\underline{p}$ < .05).

2. SWITCH STATUS CODES

A MANOVA was also run to see if pilot performance differed among the four switch status codes used in the study. The results of this MANOVA indicated no significant performance differences among the four codes ($\underline{F}$ < 1.0). The questionnaire data also indicated no significant pilot preference for any of the four methods.

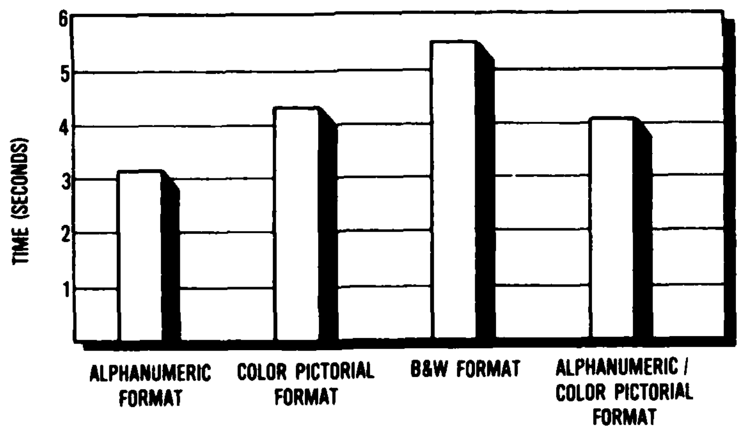


Figure 10. Mean Response Time for Each Store Format

SECTION VI

RECOMMENDATIONS

1. STORES FORMATS

From the performance and error data it can probably be said that the alphanumeric format is the most efficient format to use for a stores management display in fighter aircraft; however, when the subjective questionnaire data is examined pilots preferred the combination of the alphanumeric and color pictorial formats. One of the pilot's questionnaire comments pointed to the reason for this preference--"The color pictorial with alphanumeric allows for a quick glance at the picture and, if there is any confusion, the alphanumerics back it up." Several pilots alluded to the benefit of obtaining information from the color pictorial format easily at a glance. The reason the color pictorial display did not show this advantage in the data is not apparent but it may be due to the novelty of the display to the pilots or that the questions asked may have been biased towards the alphanumeric format. Perhaps future research could address this question more thoroughly to determine if there is any real basis for the pilot's preference of the color pictorial/alphanumeric combination.

One possible reason the color pictorial/alphanumeric format was preferred is that rapid information retrieval is very important to fighter pilots in complex tactical situations where workload tends to be very high and seconds can mean the difference between mission success or failure. The ability of the color pictorial display to provide stores management information at a glance thus becomes very important in contributing to the pilot's situational awareness of the tactical environment. A quote from Silverstein (Reference 5) alludes to a possible explanation of why the color pictorial format was preferred but showed no performance differences.

> "A color information display may or may not produce measurable, significant performance advantages over a well-designed monochromatic display in a particular application. However, regardless of measured performance, display users exhibit a general preference for color over monochromatic presentations. In the extensive review of color

coding research ... Pilots have been found to be highly consistent in their preference for color in electronics aircraft displays and tend to select vivid, highly-saturated colors for display coding.

Many questions regarding the impact of color on display operators remain unanswered. While the appeal of color is almost uniform across applications, measured performance often does not support the benefits of color coding information displays. Yet, the explanations offered by operators in defense of their preference for color are generally plausible. Are objective performance evaluations of the relative benefits of color obtained under too restricted a range of operational conditions? Perhaps the performance measures we often choose are too insensitive to detect subtle satisfactory reconciliation between preference and performance awaits future research."

A study of the type Silverstein suggested to investigate preference and performance differences was conducted on the formats used in the present research by Stollings (Reference 6). In the present study pilots were provided as much time as they needed, up to 30 seconds, to answer the stores question; however, Stollings presented the formats for only fractions of a second. The results of Stolling's study showed the color pictorial format performed better than the alphanumeric format, indicating that the advantage of the color pictorial format is in fact the ability to provide information at a glance.

Therefore, based upon this discussion, it is recommended that future fighter aircraft include a combination of color pictorial and alphanumeric information. Also, it is recommended that display designers search for other aspects of information display that can benefit from the application of color pictorial displays.

2. SWITCH STATUS CODES

Since no significant difference (objective or subjective) was found among the four methods of coding switch information, it is recommended that any of the four methods evaluated can be used to indicate switch status.

APPENDIX A

HEAD-UP DISPLAY (HUD) FORMAT

(See Figure 3)

In addition to the Stores Status Format and MFC, the head-up display was used in the present study to provide additional information for the pilot. The following paragraphs describe the HUD display format in detail.

The horizon and flight path angle lines of the flight path scale represented the horizon and each five degrees of flight path angle (FPA) between plus and minus 90 degrees. Positive FPA was presented as solid lines and appeared above the horizon line. Negative FPA was presented as dashed lines and appeared below the horizon line. The five-degree increments were numbered on either end of the FPA lines. A minus sign preceded the numbers for negative angles.

The aircraft velocity vector was represented by a flight path marker (FPM) which denoted the point toward which the aircraft was flying at all times. The FPM moved horizontally and vertically, but was not roll stabilized to show bank angle. Rather, the flight path scales and their associated numbers were roll-stabilized and rotated to the appropriate bank angle.

The airspeed, heading, and altitude scales were not roll-stabilized. The airspeed and altitude scales were vertical and appeared on the left and right sides of the display, respectively. The heading scale was horizontal and appeared at the top of the display. The airspeed scale was graduated in 25-knot increments and numbered each 50 knots. At least three sets of numbers were visible at all times. An exact readout of current airspeed was presented in the window in the center of the scale. This readout changed whenever the airspeed changed by one knot. The scale numerics were not superimposed over the window display, but were removed in that area from the CRT. Calibrated airspeed was displayed and the abbreviation CAS appeared below the airspeed scale.

Barometric altitude was displayed on the altitude scale on the right side of the HUD. The scale was graduated in 250-foot increments, numbered

each 500 feet, with at least three sets of numbers visible at all times. The total range of the altitude scale was from minus 1,000 feet to plus 99,999 feet with 1,500 feet in view at all times. An exact readout of the altitude was provided in the window in the center of the scale. The readout changed whenever the altitude changed by one foot. The scale numerics were not superimposed over the window, but were removed in that area from the CRT. When a 500-foot scale mark moved off the scale, the numerics were removed at that end. Numerical digits were added to the scale when a 500-foot mark was added to the scale as it moved.

The heading scale was displayed at the top of the HUD. Forty scale degrees were in view at all times, graduated in five-degree increments, with two digit numbers every ten degrees. Total heading scale range was 360 degrees. The aircraft magnetic heading was displayed to the nearest degree in the window. The scale numerics were not superimposed over the window, but were removed in that area from the CRT. When a 10-degree mark moved out of the field-of-view, two digits were removed at that end. Two digits were added to the scale when a ten-degree mark was added to the scale.

The flight director symbol indicated horizontal and vertical steering error information with respect to the flight path marker. The X, Y commands to position the flight director symbol were such that the pilot flew the flight path marker to the flight director by steering the aircraft in pitch and/or bank angle, i.e., the flight director was moved by the software to the flight path marker when it received the proper control signals.

Alphanumeric readouts were provided in the corners of the HUD. The vertical velocity was displayed (above altitude scale) in digital form with the readout changing in 1-foot per minute increments over a range of 0 to 9,999 feet per minute. A caret indicated vertical velocity direction, i.e., up or down. An abbreviation designating the current flight segment appeared below the altitude scale. The abbreviation CCIP was displayed during the mission. The mach number was displayed in numerical form in the upper left corner of the HUD. The digital readout changed each .01 increment of mach up to mach 2.

APPENDIX B

MFC LOGIC

A brief description of each operating sequence is shown below by task type for the branching logic (B) and for the tailored logic (T). Notations indicating when the switch status codes for DEK activation (D on) and subsystem activation (F on) were presented are included as well as notations indicating when they disappeared (D off and F off).

1. SET UHF FREQUENCY DIFFERENT FROM PREVIOUS FREQUENCY

B. The pilot selected the COMM system select switch, UHF and UHF CHNG (D on) multifunction switches, four digits and ENTER (D off) on the DEK.

T. The pilot selected the UHF CHNG (D on) multifunction switch, four digits and ENTER (D off) on the DEK.

2. CHANGE IFF CODE FOR MODE 1

B. The pilot selected the COMM system select switch, IFF and MODE 1 (D on) multifunction switches, two digits and ENTER (D off) on the DEK.

T. The pilot selected the IFF multifunction switch (D on), the digit 1, two digits, and ENTER (D off) on the DEK.

3. CHANGE IFF CODE FOR MODE 3

B. The pilot selected the COMM system selected switch, IFF multifunction switch, MODE 3 multifunction switch (D on), four digits, and ENTER (D off) on the DEK.

T. The pilot selected the IFF multifunction switch (D on), the digit 3, four digits, and ENTER (D off) on the DEK.

4. CHANGE IFF NORMAL/LOW/STANDBY STATE

B. The pilot selected the COMM system select switch and the IFF multifunction switch. Then the pilot pushed the NORMAL/LOW/STANDBY multifunction switch to change the IFF operating state (F code remains on).

5. CHANGE TACAN CHANNEL

B. The pilot selected the NAV system select switch, TCN and TCN CHNG (D on) multifunction switches, three digits, the letter X or Y and ENTER (D off) on the DEK.

T. The pilot selected the TCN CHNG (D on) multifunction switch, three digits, the letter X or Y and ENTER (D off) on the DEK.

6. ENGAGE FLY TO FUNCTION TO PREVIOUS SETTING (I)

B. The pilot selected the NAV system select switch, STEER SELECT and FLY TO (D on) multifunction switches and ENTER (D off, F on) on the DEK.

T. The pilot selected the FLY TO (D on) multifunction switch and ENTER (D off, F on) on the DEK.

7. CHANGE FLY TO SETTING (II)

B. The pilot selected the NAV system select switch, STEER SELECT and FLY TO (F off, D on) multifunction switches, one digit and ENTER (D off, F on) on the DEK.

T. The pilot selected the FLY TO (F off, D on) multifunction switch, one digit and ENTER (D off, F on) on the DEK.

8. DISENGAGE FLY TO FUNCTION (III)

B. The pilot selected the NAV system select switch, STEER SELECT and FLY TO (F off, D on) multifunction switches and ENTER (D off) on the DEK.

T. The pilot selected the FLY TO (F off, D on) multifunction switch and ENTER (D off) on the DEK.

APPENDIX C

MFC STATUS DISPLAY DESCRIPTION

Line 1 - Normally blank. When Switch 1 was activated, the previous UHF radio frequency and/or channel was displayed (UHF PREV XXX.X). When Switch 2 was activated the previous TACAN channel was displayed (TCN PREV XXXX). Line 1 became blank five seconds after the DEK deactivated.

Line 2 - Normally blank. Messages informing the operator of improper digit selections or attempted entry of the wrong number of digits were displayed (BAD DATA, CHECK DATA, or REENTER DATA). The error message disappeared with the appropriate MFC or DEK action.

Line 3 - UHF command radio status (UHF OFF, UHF T/R+G, UHF T/R, UHF ADF).

Line 4 - VHF radio status (VHF OFF or VHF T/R XXX.XX).

Line 5 - ADF/AUX UHF radio status (AUX OFF, AUX ADF XX, AUX CMD XX, or AUX GRD).

Line 6 - External fuel tank status (EXT FUEL OFF or EXT FUEL ON). ECM status (ECM OFF, ECM STBY or ECM ON).

Line 7 - TACAN status (TCN OFF, TCN REC, TCN T/R, TCN A/A REC or TCN A/A T/R).

Line 8 - Navigation mode (NAV NORM, NAV TACAN, etc.).

Line 9 - Normally blank. Latitude set in IMS, FLY TO or FLY TO TGT.

Line 10 - Normally blank. Longitude set in IMS, FLY TO or FLY TO TGT.

Line 11 - IFF status (IFF OFF, IFF STBY, IFF LOW, IFF NORM or IFF EMERG).

Line 12 - Two digit code set in Mode 1 (1 XX).

Line 13 - Four digit code set in Mode 2 (2 XXXX).

Line 14 - Four digit code set in Mode 3 (3 XXXX).

APPENDIX D

EXPERIMENTERS' CONSOLE AND SIMULATOR FACILITIES

1. EXPERIMENTERS' CONSOLE

The console was equipped with CRT displays and status light matrices which provided the experimenters with the capability of monitoring the displays in the simulator and the actual actions. A layout of the experimenters' console is shown in Figure D1. The following list specifies the functions allocated to each piece of equipment on the console that was used in the present study. Each letter refers to the notations used on the layout.

A = Status display (Figure D2); presented flight and task event information

B = Repeater display of multifunction switch legends on the MFC

C = Repeater display of the top right CRT

D = Repeater display of HUD

E = Repeater display of the bottom right CRT

F = Repeater display of the lower center CRT

G = Status panel lights; each status light stayed lit as long as the corresponding switch in the cockpit was activated.

H = Master power switch for facility

I = Abort switch for McFadden flight control systems

J = Interphone options (Note: the pilot's mike was always hot.)

K = On/off switch for interphone system

L = Switch enabling communication between two experimenters

M = Switch enabling experimenter/pilot communication

N = Switch enabling experimenter/computer personnel communication

O = Switch enabling communication between experimenters, pilot and computer personnel

P = Volume control for headset

Q = Voice recorder options

R = Run switch for voice recorder

S = Pause switch for voice recorder

T = Reset switch for McFadden system

U = Pre-event switch; activation initiated 30 seconds of flight data recording

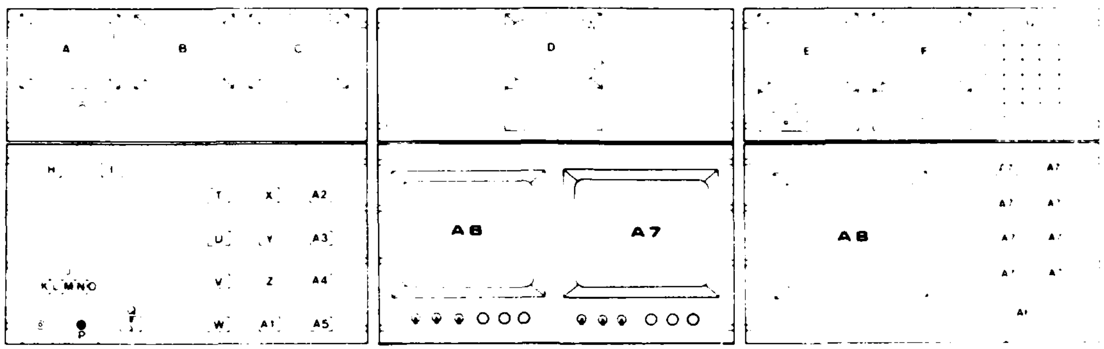


Figure D1. Layout of the Experimenters' Console

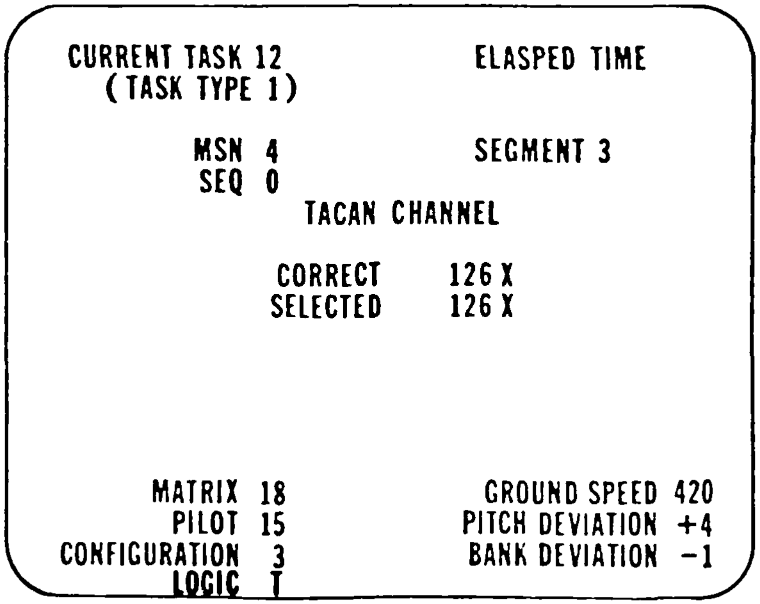


Figure D2. Status Display on the Experimenters Console

V = Event marker switch; activation started recording of task event data and unlocked MFC

W = Mission complete switch (guarded); activation initiated the computerized data reduction procedures

X = Run switch for simulation

Z = Keyboard unlock switch; activation unlocked MFC in those task events where recording terminated after the pilot entered incorrect legal digits

A1 = Indicated whether tape recording was continual or voice activated

A2 = Hold switch for simulation

A4 = Segment complete switch (guarded); activation terminated test flight and automatically updated the controls/displays configuration to that specified by the next higher matrix number. The automatic sequencing could be overridden via input on the terminal.

A5 = Task abort switch (guarded); activation terminated recording of task event data and initialized system for next task event.

A6 = Repeater display of upper left CRT

A7 = Repeater display of lower left CRT (MFC)

A12 = Volume control for headset

2. SIMULATION FACILITIES

The simulator consisted of interconnected facilities as shown in Figure D3. A functional description of each system element is provided below.

a. PDP 11/50

(1) Configuration Control

Used to set up the cockpit controls/displays configuration prior to each flight.

(2) Display Assembly

Generated image listings were to be further processed by the Ramtek raster symbol generator. Data from the simulation models was used for the HUD, VSF, and SF formats.

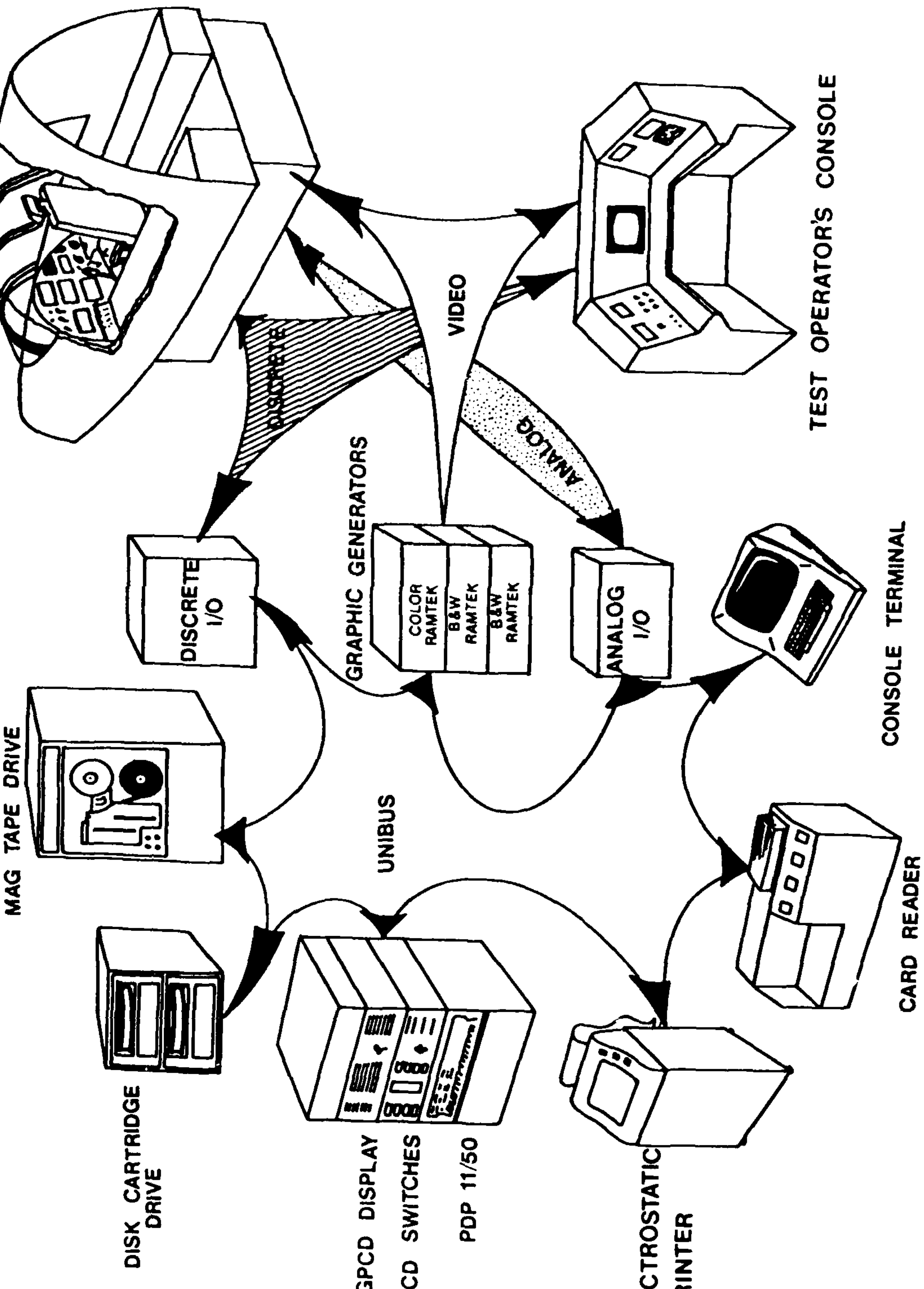


Figure D3. Simulation Facility

(3) Map Driver

Provided output control of map data to the Ramtek symbol generator.

(4) Keyboard Logic

Processed incoming switch data and determined the display state of all the keyboards.

(5) Flight Control Sampling and Scaling

Buffered and scaled flight control data to be used by simulation models.

(6) Simulation Models

Provided all necessary aircraft parameters to be used in display processing.

(7) Data Recording

Recorded cockpit display parameter data on magnetic tape.

(8) Data Reduction

An off-line program reduced the raw real-time recorded data into meaningful data that could be analyzed.

b. Ramtek

Display Generation - processed image lists to display HUD, HSF, and Stores Format on 480 line raster monitors.

c. Cockpit

(1) Keyboard Input/Output

Provided a switch image buffer of all cockpit switch states to be sampled by the 11/50. Also decoded keyboard display data being sent from the 11/50.

(2) Flight Control

Digitized analog stick, rudder, and thrust control inputs and buffered the resultant data for transmission to the 11/50.

d. Support Equipment

(1) Console Terminal

System operators input/output device to the 11/50.

(2) Printer and Card Reader

Hard copy input/output to the 11/50.

(3) Disk Drive

Mass storage device for the operating system.

(4) Magnetic Tape Drive

Mass storage device for data collection.

(5) Discrete and Analog Input/Output

Input/output port from the 11/50 to all cockpit and experimenters' console subsystems.

APPENDIX E

EXPERIMENTAL DESIGN

TABLE E1

TEST MATRIX

MATRIX	PILOT	STORES FORMAT	SWITCH STATUS	MSN	MATRIX	PILOT	STORES FORMAT	SWITCH CODE	MSN
1	1	2	4	2	33	9	1	3	5
2	1	1	1	1	34	9	2	2	6
3	1	3	3	3	35	9	3	1	7
4	1	4	2	4	36	9	4	4	8
5	2	1	1	2	37	10	2	2	7
6	2	4	2	1	38	10	4	4	5
7	2	2	4	3	39	10	1	3	6
8	2	3	3	4	40	10	3	1	8
9	3	3	3	1	41	11	3	1	5
10	3	2	4	4	42	11	1	3	7
11	3	4	2	2	43	11	4	4	6
12	3	1	1	3	44	11	2	2	8
13	4	4	2	3	45	12	4	4	7
14	4	3	3	2	46	12	3	1	6
15	4	1	1	4	47	12	2	2	5
16	4	2	4	1	48	12	1	3	8
17	5	1	2	1	49	13	4	1	8
18	5	3	4	3	50	13	3	2	7
19	5	2	1	2	51	13	1	4	5
20	5	4	3	4	52	13	2	3	6
21	6	3	4	4	53	14	3	2	8
22	6	4	3	1	54	14	2	3	7
23	6	1	2	2	55	14	4	1	5
24	6	2	1	3	56	14	1	4	6
25	7	2	1	4	57	15	1	4	7
26	7	1	2	3	58	15	4	1	6
27	7	4	3	2	59	15	2	3	8
28	7	3	4	1	60	15	3	2	5
29	8	4	3	3	61	16	2	3	5
30	8	2	1	1	62	16	1	4	8
31	8	3	4	2	63	16	3	2	6
32	8	1	2	4	64	16	4	1	7

STORES FORMAT
1 - Alphanumeric
2 - B/W pictorial
3 - Color pictorial
4 - Color pictorial & Alphanumeric

SWITCH STATUS	DEK	FUNCTION
1	Rev Video	Rev Video
2	Rev Video	Box
3	Gn Rev Video	Green Legend
4	Gn Cursor	Green Legend

TABLE E2

STORES FORMAT [illegible] STATUS CODES/BY PILOT

Switch Status Method		STORES FORMAT				
		Alpha-numeric	B/W Pictorial	Color Pictorial	Color Pictorial & Alpha-numeric	TOTAL
B/W:	RV/RV	Pilot 1-4 (n=4)	P5 - 8	P9 -12	P13-16	n=16
B/W:	RV/BOX	P5 - 8	P9 -12	P13-16	P1 - 4	n=16
COLOR:	GRV/G	P9 -12	P13-16	P1 - 4	P5 - 8	n=16
COLOR:	GC/G	P13-16	P1 - 4	P5 - 8	P9 -12	n=16
TOTAL		n=16	n=16	n=16	n=16	

KEY TO TABLE E2

STORES FORMATS

ALPHANUMERIC -- no pictorial format, status on switches 6, 7, 8, 9 and center of CCIP MFK Page 1

B/W PICTORIAL -- monochrome pictorial format, no status on MFK

COLOR PICTORIAL -- color pictorial format, no status on MFK

COLOR PICTORIAL & ALPHANUMERIC -- color pictorial format, status on switches 6, 7, 8, 9 and center of CCIP MFK Page 1

SWITCH STATUS CODES

	INDICATES SWITCH SELECTION ACTIVATES DEK	INDICATES SWITCH SELECTION ACTIVATES FUNCTION
Monochrome		
RV/RV	Black legend on white field	Black legend on white field
RV/Box	Black legend on white field	Legend in white box
Color		
GRV/G	Black legend on green field	Legend in green
GC/G	Green cursor by white legend	Legend in green

TABLE E3

DATA MISSION/STORES LOAD/QUESTION TYPE
ASSIGNMENT FOR EACH PILOT

		LOAD COMPLEXITY LEVEL 1		2		3		4	
		LOAD							
		1	2	3	4	5	6	7	8
	MISSION 1*	1	2	3	4	5	6	7	8
PILOTS	MISSION 2	2	3	4	5	6	7	8	1
1-8	MISSION 3	3	4	5	6	7	8	1	2
	MISSION 4	4	5	6	7	8	1	2	3
Stores question type**									
	MISSION 5	5	6	7	8	1	2	3	4
PILOTS	MISSION 6	6	7	8	1	2	3	4	5
9-16	MISSION 7	7	8	1	2	3	4	5	6
	MISSION 8	8	1	2	3	4	5	6	7

* Each mission flown twice (by different pilots) with each stores format (see Table 6).

** Stores question type: type (1), quantity (2), drop mode (3), interval (4), stations (5), fuzing (6), master arm or ECM status (7), hung bomb status (8).

TABLE E4

TRAINING MISSIONS/STORES LOAD/QUESTION TYPE
ASSIGNMENT FOR EACH PILOT

	LOAD COMPLEXITY LEVEL 1		2		3		4	
	TRAINING LOADS							
TRAINING MISSIONS	1	2	3	4	5	6	7	8
1	6	5	3	8	1	7	4	2
	(n=16)							
2	8	3	1	6	4	2	7	5
3	4	7	5	2	3	8	6	1
4	2	1	4	7	6	5	3	8

Stores question type*

* Stores question type: type (1), quantity (2), drop mode (3), interval (4), stations (5), fuzing (6), master arm or ECM (7), hung bomb status (8).

(Across training missions, each question type was presented at each complexity level once.)

APPENDIX F

DAILY TEST SCHEDULE

The daily test schedule is shown in Table F1. Times for cockpit familiarization, training flights, test flights, simulator reconfigurations, questionnaire completion, data verification, and final debriefing are indicated. As was mentioned in Paragraph 4.4.1 each pilot participated in an extensive briefing at his home base prior to the on-site testing.

TABLE F1

TEST SCHEDULE

0800 - 0900	Cockpit Briefing
0900 - 0915	Break
0915 - 0945	Briefing Training Flight 1
0945 - 1015	Data Flight 1
1015 - 1030	Completion of Questionnaire/Break
1030 - 1100	Briefing/Training Flight 2
1100 - 1130	Data Flight 2
1130 - 1145	Completion of Questionnaire/Break
1145 - 1245	Lunch
1245 - 1315	Briefing/Training Flight 3
1315 - 1345	Data Flight 3
1345 - 1400	Completion of Questionnaire/Break
1400 - 1430	Briefing/Training Flight 4
1430 - 1500	Data Flight 4
1500 - 1515	Completion of Questionnaire
1515 - 1600	Completion of Final Questionnaire Debriefing

APPENDIX G

SCRIPT FOR DATA MISSION 1

Barfly 11: This is Boxcar. How do you read?

Barfly 11: Roger, you are loud and clear.

PE

Task 1 (Quantity-2)

Barfly 11: Squawk Normal.

Barfly 11: I read your squawk.

PE

Task 3 (FLY TO I-2)

Barfly 11: Engage FLY TO and proceed to Waypoint Mike.

Barfly 11: Roger.

PE

Task 4 (FLY TO II-3)

Barfly 11: Change your FLY TO setting to November.

Barfly 11: Roger.

PE

Task 5 (Drop Mode - SN)

Barfly 11: What is your drop mode?

Barfly 11: Roger.

PE

Task 6 (UHF-348.0)

Barfly 11: Contact Bookcase on Bravo.

Barfly 11: You are loud and clear.

PE

Task 7 (Interval-55 FT)

Barfly 11: What interval do you have selected?

Barfly 11: Roger.

PE

Task 8 (FLY TO III)

Barfly 11: Disengage the FLY TO function.

Barfly 11: Roger.

PE

Task 9 (IFF Mode 1-51)

Barfly 11: Change your Mode 1 Squawk to Hotel.

Barfly 11: I read your squawk.

PE

Task 10 (Status - M/A Off)

Barfly 11: What's the status of your Master Arm Switch?

Barfly 11: Roger.

PE

Task 11 (Status - Hung Stores-No)

Barfly 11: Do you have any hung stores?

Barfly 11: Roger.

PE

Task 12 (Type-MK82)

Barfly 11: What type store is selected?

Barfly 11: Roger.

PE

Task 13 (Fuze-None)

Barfly 11: What fuzing do you have selected?

Barfly 11: Roger.

PE

Task 14 (TACAN-116Y)

Barfly 11: Tune your TACAN to Echo.

Barfly 11: Roger.

PE

Task 15 (IFF, Mode 3-2100)

Barfly 11: Change your Mode 3 Squawk to Kilo.

Barfly 11: I read your squawk.

PE

Task 16 (Stations - 2 & 7)

Barfly 11: Which station or stations have you selected?

Barfly 11: Roger.

Track Advance

Accelerate to 450 knots. At waypoint six the Flight Director will present a fly up command (approximately 25^{0} positive flight path angle). Go to full throttle and maintain the flight director centered. Follow fly down command (approximately 5^{0} negative flight path angle). When airspeed reaches 450 knots, retard throttle to idle. When the solution cue passes the "wingtips" of the velocity vector, activate the bomb release button.

Mission Complete

APPENDIX H

STORES AND SWITCH STATUS EVALUATION

FINAL DEBRIEFING QUESTIONNAIRE AND RESULTS

We are doing a study to determine the best method of presenting stores and MFC switch selection status from an operational standpoint. The results of this study will determine what ground rules should be used in designing future generation crew stations. One of the best sources of information in terms of improving avionics designs and avoiding mistakes of the past is to talk directly with those who fly operational aircraft. Your candid opinion will help a great deal in achieving this goal. The questionaire is divided into four parts:

Part 1 PERSONAL DATA -- Information related to your background will be collected.

Part 2 STORES STATUS FORMAT -- More information related to the stores format will be obtained.

Part 3 MULTIFUNCTION CONTROL (MFC) -- Additional information related to the use of the MFK and the switch status codes will be recorded.

Part 4 OTHER SIMULATOR CONTROLS AND DISPLAYS -- Information concerning the other display formats, controls, simulator quality, or testing procedures will be recorded.

Most of the questions can be answered with a single check (✓) (only check <u>one</u> block); however, any additional comments that you may provide will be very helpful. Please be as specific as you can.

PART 1

PERSONAL DATA

Name ______________________ Age $\bar{x}$ = 35.56 yrs.

ANG UNIT ______________________

Present Duty Title ______________________

Total Flying Time 40,850 = x hrs. $\bar{x}$ = 2553.13

Total Jet Time 30,950 = x hrs. $\bar{x}$ = 2309

Time in A-7 17,000 = x hrs. $\bar{x}$ = 1062.5

Other Fighter Aircraft Flown

______________________ __________ hrs.

______________________ __________ hrs.

______________________ __________ hrs.

______________________ __________ hrs.

______________________ __________ hrs.

Total Years Rated 194 = x $\bar{x}$ = 12.13 yrs.

Civilian Job ______________________

Indicate the number of operational/training missions with the following stores:

	None	1-10 Missions	More than 10 Missions
ECM Pods	9	5	2
BLUs	5	7	4
MK-82s	1	5	10
CBUs	12	2	2
AIM-9s	3	8	5

PART 2

STORES STATUS FORMATS

1. Compare the four formats in terms of ability to cross-check the status of all stores' parameters (fuzing, quantity, etc.).

	Worse Than	Slightly Worse Than	Equal To	Slightly Better Than	Better Than	
Alphanumeric	0	6	1	3	6	B/W Pictorial
Alphanumeric	4	4	3	5	0	Color Pictorial
Alphanumeric	11*	4	0	1	0	Color Pictorial & Alphanumeric
B/W Pictorial	9*	6	1	0	0	Color Pictorial
B/W Pictorial	15*	0	1	0	0	Color Pictorial & Alphanumeric
Color Pictorial	3*	12	1	0	0	Color Pictorial & Alphanumeric

*$p < .05$

2. Was there a parameter(s) (fuzing, quantity, etc.) for which the information displayed was particularly useful?

1. 'Hung, Fuzing, Interval, Selection, and Type of Store.'
2. 'Interval'
3. 'Pictorials were best for telling where the ordinance is and where it will be coming off when you drop.
   Pictorial is much better than alphanumeric for this.'
4. 'Interval on pictorial was very easy to use but not all that useful.
   Quantity selected would be nice there.'
5. 'Humg bomb.'
6. 'Interval, quantity, fuzing, stations.'
7. 'Bomb format, location, and status is very useful.'

8. 'Interval and Fuzing.
9. 'Weapons information by the switch itself was good.'
10. 'Quantity, alphanumeric, and station.
11. 'Quantity and station.'
12. 'Hung bombs, nose/tail fuzing at a glance.'
13. 'Hung bombs and master arm.'
14. 'Hung bombs and fuzing.'
15. 'No, all equally useful.'
16. 'Green color for Armed was useful. Interval was easy to read.'

3. Was there a parameter(s) (fuzing, quantity, etc.) for which the information displayed was particularly inadequate?

Comments/Improvements:

1. 'The cursor is too small-perhaps use a different color or an asterisk. The flash of the hung store is too slow on the CRT and the numbers are too fast on the HUD.'
2. "Hung store hard to discern w/master arm off make thicker outline or move outline in from edge.'
3. 'Station numbers on pictorials--would help to set up options etc.'
4. 'The pairs/single/salvo triangle was difficult to use because you had to scan the whole picture to pick them out. The idea is beautiful. If you combine the alphanumeric with the pictorial to provide a little more useful information in one area you've got it, but you have to be able to pick out the information in a quick scan.'
5. 'Hung bomb--always red or always flashing would be more consistent. Mode indicator (V) was confusing on Napalm, it looked like a fin. A small alphanumeric on the pictorial display with Qty. would save counting when quantity is large. Fuel tanks--were confusing when asked what stations were selected.'
6. 'The master arm switch without color was confusing.'
7. 'Hung (non-selected bomb) in color pictorial. Darker (wider) dashed red outline.
8. 'Singles/pairs indication in the pictorial format doesn't jump out at you. Station numbers across top of display would be helpful, since when stations 2 and 3 are fully loaded, there could be a resolution problem.'

9. 'I did not especially like singles/pairs representation and I definitely did not like the fact that I did not know what quantity of bombs selected were going to be released.
10. 'Bomb quantity on pictorial only. Improv.--Station selection on pictorial B & W. Need heavier station selection line on B & W pictorial.
11. 'Hung ordinance in the color pictorial.'
12. 'Total number selected has to be counted. Need quick selection of number of bombs selected and simple pairs, single, cluster etc. switch.'
13. 'Hung bomb with master arm off. Could not see red lines. Suggest using the work 'HUNG' also flashing symbology to depict hung bombs was not good.'
14. 'Black and white pictorial' Improvement #1. On the alphanumeric for station selection use a hyphen. #2. Black and white pictorial for hung bombs should not be a flashing symbol as this can be missed when only a quick glance can be taken at the set.
15. 'Pictorial not good for single/pairs or quantity.'

4. Rank order the five configurations in terms of acceptability and usability (1 - best).

		RANKING ACROSS PILOTS				
		1	2	3	4	5
4	Alphanumeric Format[1]	1	6	1	5	2
3*	Black/White Pictorial Format	0	1	4	4	7
2	Color Pictorial Format	0	7	7	1	0
1*	Color Pictorial and Alphanumeric Formats	14	1	0	1	0
5	Conventional Electromechanical	0	2	3	4	7

*p < .05

[1]One pilot ranked alphanumeric and color pictorial format equal.

Why?

1. CP&A - The information is easier to understand and to change.
2. CP&A - Due to ease of readability and amount of information available.
3. CP&A - The only reason the alphanumeric was to pick out information that I could not get quickly enough, or that I had to think very

long about to understand on the pictorial. In single seat fighters, all cockpit information must be gotten in a quick scan or Ivan's gonna taxi up a six and stick a missile in your tush!

4. CP&A - 1. Easy to use because of quantity of data. Can see what ordinance is on board A/C. 2. Familiarity, mostly. Easy to determine fuzing, selection of wing stations, master arm. 3. Tie because some data (quantity for instance) easier w/alphan., but other parameters (master arm) easier pictorially. 4. Tie. 5. Hard to use!
5. Alph. - Best--Because you didn't have to do anything but find the information. The picture you have to interpret.
6. CP&A - #1 provides a reassuring cross check that will reinforce learning and habit patterns. Alph. and C.P. almost a tossup. B/W is confusing and requires too much attention.
7. CP&A - I think the "color" approach and pictorial display is on the right track, but if you are clever you can probably get all the information on the pictorial and eliminate the alphanumeric stuff.
8. CP&A - Alphanumeric only helped fill in gaps for quantity and pairs or single and fuzing. Suggest this information be put on pictorial screen bottom and do away with alpha screen.
9. CP&A - Both together could be quickly surveyed at a glance.
10. CP&A - Color pictorial was easy to get information with only a quick glance--especially fuzing options.

5. Which stores status configuration or combination of configurations would you like to see in future cockpits.

 1 Alphanumeric[1]
 0 Black/White Pictorial Format
 5 Color Pictorial Format
 11 Color Pictorial and Alphanumeric Format
 3 Other (please describe)
 0 Other (please describe)

[1] Some pilots responded more than once.

Why?

1. A-7 switches are well laid out and easy to see and use. The color pictorial gives slightly more information.

2. CP&A - Easiest to use.
3. CP - It's the easiest to read. But again combined with the alphanumeric. You started to do it with the interval, now go one step further.
4. CP&A/Conv. - For complicated scenarios involving numerous types of ordinance, the alphanumeric/pictorial is convenient, as it can be pre-programmed. In the real world situation, however, I doubt that such an ordinance mix would occur, other than not having a display of ordinance remaining, I find the present electromechanical system to be easy and efficient to use.
5. CP&A - The color alone is not enough. There is possible confusion interpreting the picture. But with both the alphanumeric format and color pictorial - accuracy increases.
6. CP&A - Chance of error is reduced exponentially with redundant displays.
7. CP - Color alphanumeric would be good -- call it up at pilots option.
8. CP&A - But only alphanumeric information needed is fuzing (NT, etc.) quantity, and pairs/single.
9. CP&A - Pictorial for position of ordinances.
10. CP - Simple to interpret.
11. CP&A - I would like to see what I have selected but I like toggle switches to do the selecting.
12. CP - I think this will be easiest to decipher after it has been perfected.
13. CP&A - The pictorial with alphanumeric allows for a quick glance at the picture and if there is any confusion the alphanumerics can back it up. With only one system I prefer the alphanumerics to eliminate any possible confusion.
14. CP&A - Color pictorial shows fuzing and stations and alphanumerics shows pairs/singles to quantity. Conventional to actually select stations.

6. Compare each status format in terms of its acceptability for the following aspects:

Type - indication of what has been selected

	Worse Than	Equal To	Better Than	
Alphanumeric	2*	3	11	B/W Pictorial
Alphanumeric	5	6	5	Color Pictorial
Alphanumeric	12*	1	3	Color Pictorial and Alphanumeric
B/W Pictorial	13*	3	0	Color Pictorial
B/W Pictorial	15*	1	0	Color Pictorial and Alphanumeric
Color Pictorial	11*	4	1	Color Pictorial and Alphanumeric

*p < .05

1. 'Difficult distinguishing between ripple of many or salvo.'

Fuzing - indication of weapon fuzing status

	Worse Than	Equal To	Better Than	
Alphanumeric	6	3	7	B/W Pictorial
Alphanumeric	9	2	5	Color Pictorial
Alphanumeric	12*	2	2	Color Pictorial and Alphanumeric
B/W Pictorial	9*	7	0	Color Pictorial
B/W Pictorial	13*	3	0	Color Pictorial and Alphanumeric
Color Pictorial	9	6	1	Color Pictorial and Alphanumeric

Master Arm Selection - indicates master arm switch status

	Worse Than	Equal To	Better Than	
Alphanumeric	6	3	7	B/W Pictorial
Alphanumeric	9	3	4	Color Pictorial
Alphanumeric	12*	3	1	Color Pictorial and Alphanumeric
B/W Pictorial	11*	5	0	Color Pictorial
B/W Pictorial	13*	3	0	Color Pictorial and Alphanumeric
Color Pictorial	8	6	2	Color Pictorial and Alphanumeric

*p < .05

Interval - indication of weapon release interval

	Worse Than	Equal To	Better Than	
Alphanumeric	9*	7	0	B/W Pictorial'
Alphanumeric	9*	7	0	Color Pictorial
Alphanumeric	11*	5	0	Color Pictorial and Alphanumeric
B/W Pictorial	1*	15	0	Color Pictorial
B/W Pictorial	3*	13	0	Color Pictorial and Alphanumeric
Color Pictorial	2*	14	0	Color Pictorial and Alphanumeric

<u>Drop Mode</u> - indication of singles, pairs, or salvo drop mode selection

	Worse Than	Equal To	Better Than	
Alphanumeric	3*	1	12	B/W Pictorial
Alphanumeric	3*	1	12	Color Pictorial
Alphanumeric	5	7	4	Color Pictorial and Alphanumeric
B/W Pictorial	4*	12	0	Color Pictorial
B/W Pictorial	13*	3	0	Color Pictorial and Alphanumeric
Color Pictorial	12*	4	0	Color Pictorial and Alphanumeric

*$p < .05$

<u>Hung Bomb (M/A)</u> - indication of a hung bomb when master arm selected

	Worse Than	Equal To	Better Than	
Alphanumeric	4	3	9	B/W Pictorial
Alphanumeric	9	4	3	Color Pictorial
Alphanumeric	11*	4	1	Color Pictorial and Alphanumeric
B/W Pictorial	12*	3	1	Color Pictorial
B/W Pictorial	12*	4	0	Color Pictorial and Alphanumeric
Color Pictorial	6*	10	0	Color Pictorial and Alphanumeric

*$p < .05$

1. B&W Pictorial for hung bomb should be a much faster flash rate or frequency as at a glance you can miss the flash in a quick cross check.

Hung Bomb (No M/A) - indication of a hung bomb when master arm deselected

	Worse Than	Equal To	Better Than	
Alphanumeric	2	5	9	B/W Pictorial
Alphanumeric	2	4	10	Color Pictorial
Alphanumeric	6	7	3	Color Pictorial and Alphanumeric
B/W Pictorial	7	2	7	Color Pictorial
B/W Pictorial	9	3	4	Color Pictorial and Alphanumeric
Color Pictorial	10*	6	0	Color Pictorial and Alphanumeric

*$p < .05$

Comments/Improvements:

1. 'Red outline is not enough. Who cares if master arm is selected or deselected - whats important is that you are told that the bomb didn't fall.'
2. 'Spell it out to avoid confusion. The best presentation is the color alphanumeric.'
3. 'Eliminate the flashing symbol for armed B/W hung bomb. Write hung on the unarmed color symbol instead of the red border.'
4. 'Difficult to identify hung bombs on pictorial after master arm deselected.'
5. The flashing pictorial or alphanumeric is good with master arm on - the 'hung' spelled out on B/W pictorial is best for M/A off. Suggest it be used with the color also.'
6. Wider red dashed border. Also, a flashing bomb silhouette would be beneficial.
7. 'Can't see red outline - write hung on bomb and take red away when mast. arm turned off.'
8. 'Color pictorial needs a much heavier line for hung and deselected.'

9. 'Need better indication on color pictorial of hung ordinance.
10. 'Master arm off use red or B&W.

7. Rate each status format in terms of its acceptability for indicating whether the ECM Pod was selected or unselected.

	Worse Than	Equal To	Better Than	
Alphanumeric	10	4	2	B/W Pictorial
Alphanumeric	11*	3	2	Color Pictorial
Alphanumeric	12*	4	0	Color Pictorial and Alphanumeric
B/W Pictorial	8*	8	0	Color Pictorial
B/W Pictorial	10*	6	0	Color Pictorial and Alphanumeric
Color Pictorial	6*	10	0	Color Pictorial and Alphanumeric

*$p < .05$

Comments/Improvements:

1. ECM Pod display easy to use.
2. Flashing Pod silhouette while Pod is on. Tie into Pod self test circuit to indicate Pod malfunction (sort of a reverse hung bomb concept).
3. Green color was confusing since it is the same color used for ordinance. Use different or no color on Pod are great.
4. Some capability must be included to show mode, power, output, and standby functions of Pods. There are other critical factors during ingress to target besides just on and off.
5. Instead of having the ECM Pod green when on, this color should be reserved for armed weapons, write on the Pod on or off as hung is written on the unarmed hung bombs in B & W.

8. Rate each status format in terms of its acceptability in indicating the selection of the fuel tank.

	Worse Than	Equal To	Better Than	
Alphanumeric	9	3	3	B/W Pictorial
Alphanumeric	9	4	2	Color Pictorial
Alphanumeric	11*	4	0	Color Pictorial and Alphanumeric
B/W Pictorial	6	9	0	Color Pictorial
B/W Pictorial	9	6	0	Color Pictorial and Alphanumeric
Color Pictorial	3	12	0	Color Pictorial and Alphanumeric

*$p < .05$

Comments/Improvements:

1. Write on the tanks on, off or empty.
2. Delete fuel tanks from pictorial display unless selected for jettison.
3. In A-7, because we do not "select" external tank transfer, all you need is a picture showing station tank is on. Both pictorials were good.
4. Make fuel tanks "skinnier" to differentiate from BLU and make smaller.
5. Instead of bubbles, why not?
6. Did I look at this?
7. Pictorial fuel tank would be better if it also showed pictorial display of fuel remaining in tank.

9. In the pictorial formats, different shapes were chosen to represent the stores and the aircraft. How well do you feel the shapes represented the respective types. (Refer to Figure 1.)

	Unacceptable	Bad	Satisfactory	Good	Optimum
1. MK82	0*	0	2	7	7
2. CBU	0	2	5	9	0
3. BLU	0	3	8	4	1
4. AIM-9	0*	0	1	5	10
5. ECM Pod	0*	1	3	9	3
6. Fuel Tank	0	3	8	5	0
7. Aircraft	0*	0	6	9	1

*$p < .05$

Comments/Improvements:

1. Pictorial could be improved by use of alphanumeric of exact type of ordinance - BLU-4 or MK 83 etc.
2. Actual tank shape is longer and more pointed with fins. Also, tank shape is similar as Napalm. (Which means that sooner or later someone will drop a tank.)
3. Number stations and BLU fuel tanks too fat - can't tell which is on what station. CBU too complicated change to ... et al.
4. Are BLU fire bombs still in the inventory?
5. The BLU were too big and it was sometimes confusing in the pictorial as to what station they were on.
6. BLU looks a lot like the fuel tank.
7. Fuel and BLU are too much alike. Make MK82 look more like a MK82.

PART 3

MULTIFUNCTION KEYBOARD (MFC)

1. The IFF Normal/Low/Standby switch is one example of where four methods were used to indicate switch selections which activate a function. Compare the four methods below.

	Worse Than	Slightly Worse Than	Equal To	Slightly Better Than	Better Than	
Black Legend on White Field	6*	4	5	1	0	White Box and White Legend
Black Legend on White Field	7	2	2	5	0	Green Legend
White Box and White Legend	1	5	3	5	2	Green Legend

*$p < .05$

Comments/Improvements:

1. Go green but white/black ok.
2. No significant differences but green legend seemed slightly easier.
3. In black legend on white field, mechanization for IFF mode was confusing. I'd rather see white field move.
4. Black legend on any field was extremely confusing when also activating the DEK to enter something else.

2. The UHF change switch is one example of where four methods were used to indicate switch selections which activate the data entry keyboard (DEK). Compare the four methods below.

	Worse Than	Slightly Worse Than	Equal To	Slightly Better Than	Better Than	
Black Legend on White Field	3	7	6	0	0	Black Legend on Green Field
Black Legend on White Field	3	1	5	4	3	Green Cursor White Legend
White Box on Green Field	1	1	3	6	5	Green Cursor by White Legend

1. Through familiarization, didn't really look at legend. Knew which button to press.
2. I didn't pay close attention to these differences so no comment.
3. Liked black on green.
4. I liked the black legend on the green field best.
5. Black letters on white field - white was too bright causing it to be difficult to read letters and numbers - if could be dimmed it would have been equal to the green field which had a good intensity level.

3. The following describes the methods of indicating switch selections for:

FUNCTION ACTIVATION (e.g. IFF Normal/Low/Standby)	DEK ACTIVATION (e.g. UHF change)
METHOD 1: Black Legend on White Field	METHOD 1: Black Legend on White Field
METHOD 2: White Box and White Legend	METHOD 2: Black Legend on White Field
METHOD 3: Green Legend	METHOD 3: Black Legend on Green Field
METHOD 4: Green Legend	METHOD 4: Green Cursor by White Legend

Indicate below, for both codes, which method (check one in each column) you would like to see in future cockpits.[1]

	FUNCTION ACTIVATION	DEK ACTIVATION
METHOD 1	NA	NA
METHOD 2	6	3*
METHOD 3	7	10
METHOD 4	1	2
OTHER	1	0

*$p < .05$

If you checked other, please describe method:

Comments:

1. Green somehow means that things are ok - i.e. - the action taken was proper - the box accentuates this. Also, function activation would be consistent with my choice of DEK activation.
2. No preference. They're all the same.
3. Function activation is also good when using white box and white legend.
4. Can't answer this one too well since I didn't pay close attention.

4. Compare the following two methods in terms of whether the same code (Method 1) or different codes (Method 2) should be used to indicate switch selections which activate functions and switch selections which activate the DEK.

	FUNCTION ACTIVATION	DEK ACTIVATION
<u>Monochrome</u>		
METHOD 1:	Black Legend on White Field	Black Legend on White Field
METHOD 2:	White Box and White Legend	Black Legend on White Field

	Worse Than	Slightly Worse Than	Equal To	Slightly Better Than	Better Than	
CODES SAME (Method 1)	5	5	3	2	1	CODES DIFFERENT (Method 2)

Comments/Improvements:

1. Of these the white box and white legend were the easiest to read.
2. Should be different because switches and buttons get activated accidently and you should be able to tell which mode or status you are in.

5. Both function and DEK activation codes were used in the implementation of the FLY TO function. Indicate below how you found this mechanization during the FLY TO tasks: engage FLY TO function to previous setting, change FLY TO setting, and disengage FLY TO function.[1]

Unacceptable	Bad	Satisfactory	Good	Optimum
1	2	2	9	1

[1]One pilot did not respond.

Comments/Improvements:

1. Didn't like having to hit FLY TO 2nd time to get "out of". Should just be able to hit C or E. Didn't like using E instead of C either.
2. It would be so obvious to press "clear" when you want to remove "FLY TO" information, why press "enter" when you want to remove?
3. Seemed very easy.
4. Could be better if FLY TO on or off or change could be on "rotary" switch so turning on or off could be done on one button.

6a. Two types of three-way "rotary" switches were demonstrated. One was in the IFF logic and changed the system status: STANDBY, NORMAL, LOW. The other was used in the STORES logic to indicate delivery mode: SINGLES, PAIRS, SALVO.

In this study, the legends rotated in a clockwise direction, changing one position with each push of the switch, while the function activation code remained in a fixed position to indicate the active state.

Was this type of mechanization:

Unacceptable	Bad	Satisfactory	Good	Optimum
1	1	6	7	1

6b. The logic could be implemented such that the legends remain in a fixed position and the function code (e.g. white box) rotates to indicate the active state. How do you think these two implementations would compare:

	Worse Than	Slightly Worse Than	Equal To	Slightly Better Than	Better Than	
LEGENDS ROTATE	3	1	6	3	3	CODE ROTATES

Comments/Improvements:

1. It would be helpful to be able to change system status without calling up branching logic in combat. On your final run-in to target (when tasks are greatest) and on egress, you are going to have to turn IFF to standby then back to normal on egress. It's too difficult now.
2. Very seldom do we use the low function so it seems a shame to always have to cycle through it on the way to standby or normal.

7. As a result of suggestions from the pilots in a previous study, the implementation of the IFF function was changed so that Modes 1, 2, and 3 can be accessed on the tailored page, without calling up the branching logic. Indicate below how you found the procedure of selecting the mode number first followed by digits and ENTER to change a code:

Unacceptable	Bad	Satisfactory	Good	Optimum
0*	0	4	10	2

*$p < .05$

Comments/Improvements:

1. Better than before - but still takes 3-4 steps just to get from normal to standby.
2. IFF function not located in same position in the two logics. Will indull errors.
3. Would prefer only Mode 3 code changes so mechanized. Delegate req't to first press mode #.
4. In a peace-time training environment, it would be easier to punch a Mode 3 indirectly; however, in a real time world situation, the other modes would need to be changed more frequently, so the method of selecting a mode first would be easier.
5. But, you really can't change Mode 2 from cockpit. Preset in avionics bay before flight. Also Mode 4 and the operation is much more important for fighters than 1, 2, or 3.
6. I found the branching log. 2 slightly confusing in the beginning. I became use to using the tailored page for IFF mode settings. When it came time to go to normal, I kept trying to use the tailored page. With a little practice this problem should go away.

8. Considering all of the tasks completed in this test, compare the standard control heads in your aircraft with the logic implemented on the multifunction control (MFC).

Conventional Much Better Than MFC	Conventional Slightly Better Than MFC	Equal	MFC Slightly Better Than Conventional	MFC Much Better Than Conventional
1	1	3	5	6

Comments/Improvements:

1. VHF and TACAN easier on MFC, FLY TO and IFF easier in A-7.
2. Easier to work with then control heads that are all in the same location.
3. The VHF radio should not be included in the MFC. Flying on the wing in the weather, it doesn't provide enough feel for the wingsman to change frequencies.
4. Some tasks are easier using conventional controls because they can be done by feel - i.e. changing VHF radio channels from preset 1 to preset 2 or 3. Others are easier on MFC. Suggest that a way of presetting UHF channels be developed so much used frequencies can be changed with only two or three keystrokes and not five or six.
5. Accessibility of keyboard was awkward. I had to lean forward and look at keyboard. It is easy to touch-type on A-7 keyboard. I would like a tactile cue on the five button for quick reference; e.g., sandpaper finish, very sharp needle sticking out of button, etc.
6. However, it takes more getting used to. More training will be required I think.

9. The MFC control logic returned automatically from the branching logic to the tailored logic after a ten second period had elapsed since the selection of an MFC switch did not activate the DEK (e.g. IFF Normal/Low/Standby) or selection of ENTER on the DEK.

Indicate below how you found this mechanization:

Unacceptable	Bad	Satisfactory	Good	Optimum
0*	0	6	6	4

*$p < .05$

Comments/Improvements:

1. I loved the display of change in the HUD for ten seconds. This makes it easy to check your entry (if you ever get a good keyboard position) without looking down and without permanently cluttering up the HUD.
2. Ten seconds may not be long enough for a wingman in the weather.
3. Eight seconds would be better. Ten seconds seems too long.
4. Shorter time may be better.
5. But, could present problems if pilot busy and really didn't want to leave.

10. Rate each of the following aspects of the MFC:

	Unacceptable	Bad	Satisfactory	Good	Optimum
Functions[1]	0*	0	5	11	0
Legend Arrangement[2]	0*	0	7	9	0
Interpretability[3]	0*	0	4	10	2
Legibility[4]	0*	1	4	7	4
Switch/Legend Association[5]	0*	1	5	8	2
Pre-Entry Readout[6]	0*	1	6	7	2
Error Message-B/W[7]	0	2	6	6	1
Error Message-Color[7]	0*	0	3	9	4

*$p < .05$

[1]Functions -- Ten choices offered on CCIP tailored page.

[2]Legend Arrangement -- Functions assigned to each switch.

[3]Interpretability -- Ability to understand the meaning of the legends.

[4]Legibility -- Ability to read or decipher the alphanumerics.

[5]Switch/Legend Association -- Ability to select the switch corresponding to the desired legend or function.

[6]Pre-Entry Readout -- Digits selected were displayed beneath the corresponding functions legend on the MFC and on the HUD.
[7]Error Message -- Messages displayed if illegal ("BAD DATA"), too many ("CHECK DATA") or too few ("RE-ENTER DATA") digits selected. Messages yellow in color format.

Comments/Improvements:

1. "Bad data" doesn't say what is bad. May want to say "UHF limits" or "missing digits", etc.
2. *6--Pre-entry readout would be better in HUD if it did not flash or if flash "off" time was less.
3. Pre-entry readout: HUD flashes too fast!
4. Legibility--Make numbers and letters larger.
5. Due to parralax it is difficult to correlate the switch with legend. Suggest use of white lines.
6. How about red in color--or spell out "try again, dummy".
7. Didn't use 6.
8. I did not like the numbers flashing before being entered. It required too much time to check the numbers before entering them. I could only read one number clearly during each flash. The HUD display of changes is nice but should be a pilot operation. Nice at night in the weather but useless in combat.
9. Function switches were a little narrow vertically perhaps switches shaped this way would be easier to push.
10. CCIP Page - Doesn't need TACAN or IFF code change. It does need target elevation and IFF standby, normal, off.
11. More color coding would help in alphanumerics ... perhaps not on a quick test such as this, but if one flew an aircraft for a number of years and any particular piece of information was always presented in red, for instance, it would be easy to retrieve information from an otherwise busy alphanumeric screen.

11a. Rate the acceptability of presenting systems status information in the center column of the MFC.

Unacceptable	Bad	Satisfactory	Good	Optimum
0*	0	5	10	1

*$p < .05$

Comments/Improvements:

1. Didn't use it very often, just when I couldn't find the information fast enough anywhere else.
2. Radio and navigation information is good. Weapons information was confusing, too much weapons information.
3. Good, like the blue background better.
4. But hard to read. Seems to be bunched together. Maybe want to group like data.

11b. Would you rather the status be presented on a separate CRT? Why or why not?

1. No - Space the presentation on the MFK was good so there is no reason to take up another CRT with it.
2. No - You'd be wasting space for information presented pictorially elsewhere.
3. No - More convenient on same CRT.
4. Make it selectible by pilot.
5. No - Keeping it together helps keep the confusion down.
6. No - Prefer having only one place to look for information on a system.
7. No - Clustered well, systems status information easily accessible.
8. No - You only have to look in one place.
9. No - It seems fine as is.

10. No - It isn't that complicated.
11. No - Leave the status where the action part of the station is.
12. No.
13. No - It is located in a good position right beside the function switches. All information is in one location.
14. Not necessary - Seemed cluttered at first once you get used to looking for status information on the center column it would be just as good as a separate CRT.
15. No - This is ok. Just format total bothered me. I had to do a lot of reading (scanning) to find the information. Need a ball park place to start (upper left, in the middle, lower group, etc.).

PART 4
OTHER SIMULATOR CONTROLS AND DISPLAYS

In addition to the CRTs which presented stores status and MFC logic, the HUD supplied flight control information, weapons symbology, and readouts of the MFC legends corresponding to the selected MFC switches and digits. Although this display format was not of primary concern in this study, we would like to give you an opportunity to provide comments you have concerning such aspects as amount of information presented, ease of information retrieval, legibility, shape of symbols, jitter, etc. Also, feel free to comment on the controls used (besides the MFC), electro-mechanical engine instruments, simulator quality, and testing procedures. Please specify in your comments which piece of equipment or procedure you're addressing.

Thank you.

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